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JOURNAL OF ANATOMY AND
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JOURNAL OF ANATOMY AND PHYSIOLOGY

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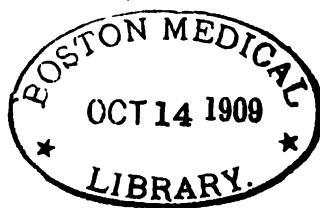
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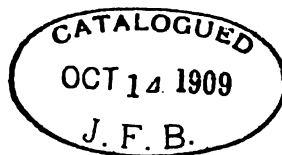
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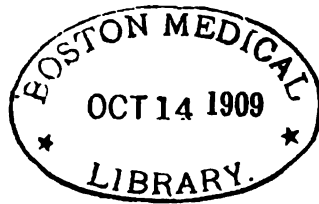
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JOURNAL OF ANATOMY AND PHYSIOLOGY

NOTE ON AN UNUSUAL ANOMALY IN CRANIA FROM THE
ISLAND OF KWAIAWATA, NEW GUINEA. By W. L. H.
DUCKWORTH, M.D., Sc.D., *University Lecturer in Physical Anthro-
pology, Cambridge.*

WHEN examining the collection of human crania brought by members of the Daniels Expedition from the islands adjacent to New Guinea, I noticed a very unusual anomaly in the immature specimen No. 130. The skull came from Kwaiawata Island.

The anomaly consists in the presence of symmetrical paired spinous processes about 3 mm. in length, projecting on either side of the apertura pyriformis nasi, just below the level at which, as in most crania of Oceanic negroes, the sharp margin of the aperture is lost. These processes are clearly visible in the accompanying photograph (fig. 1, No. 130).

Interest in the occurrence of this anomaly being thus aroused, I searched the whole series through, and found a similar, though unilateral, process in two more crania (*cf.* fig. 1, No. 133; fig. 2, No. 129). In two other cases (*cf.* fig. 2, No. 106) a distinct though only slightly elevated ridge was found to occupy a position corresponding to that of the spicular process of the preceding examples, and, as in the latter of these, was developed on one side only of the nasal aperture.

The occurrence of osseous spicules in the situation described is very rare. Professor Macalister tells me that these are the first examples of which he has heard; and Professor Le Double, to whom I have submitted the photographs, writes to the same effect. I know of no records of comparable anomalies.

The following notes are based on the examination of the Cambridge University Collection.

Apart from the crania from Kwaiawata, no others of the specimens of
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the Daniels Collection, and none of the numerous skulls from the mainland of New Guinea, present this anomaly.

In the long series of nearly eighty crania (the Willey Collection) from New Britain, a single example (*cf.* fig. 3, No. 3334) bears a ridge similar to that observed in No. 106 (fig. 2).

The large collection of ancient Peruvian skulls provided two examples (Nos. 1938 and 1972).

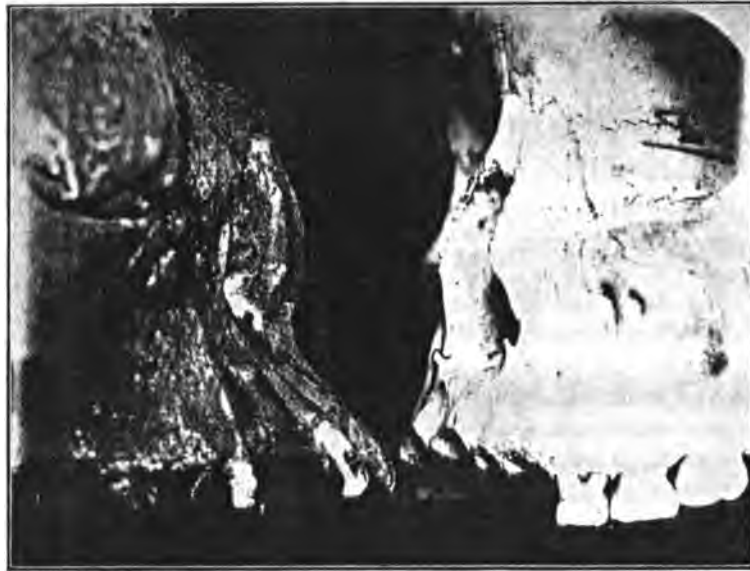


FIG. 1.—Crania from Kwaiawata (Daniels Collection, Mus. Anat. Cant.), Nos. 133 (to the left) and 139. To show the spicular processes on the margin of the nasal aperture.

A single instance occurred among the ancient British crania (No. 2574 of the Harwood Collection).

But no other examples were discovered in the extensive Cambridge Collection, which includes specimens from all parts of the globe.

Among the crania of African negroes, two present anomalous conditions of the nasal margin, but no comparison obtains between these and the subjects of these notes. In both cases the left side only of the nasal aperture is affected. In No. 1730 an indented ridge about 3 mm. long projects from the nasal margin immediately below the nasal bone. In No. 4201 a shelf-like spur juts out from the nasal process of the maxilla, and supports the left nasal bone.

Scanty as they are, these records show that the diagnostic value of the



FIG. 2.—Crania from Kwaiawata (Daniels Collection, Mus. Anat. Cant.), Nos. 129 (to the left) and 106. The former bears a spicule of bone, and, in a corresponding situation in specimen No. 106, is seen a low rough osseous ridge.

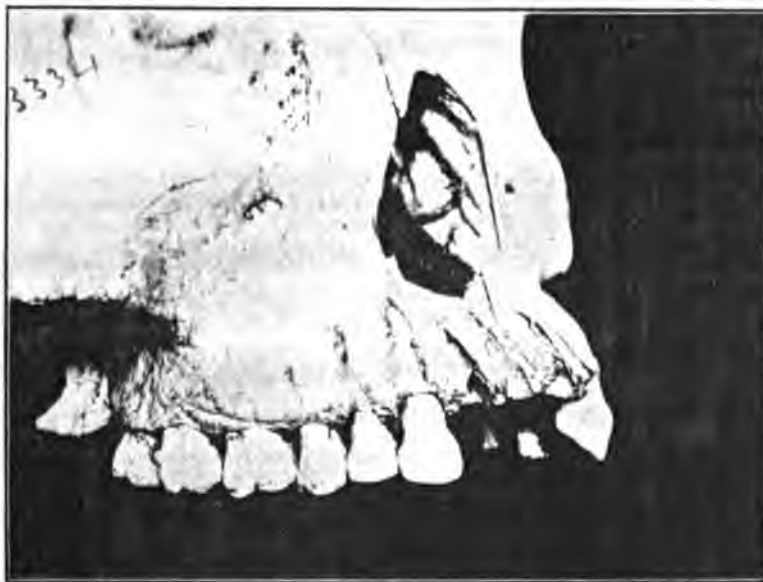


FIG. 3.—Cranium from New Britain (Willey Collection, Mus. Anat. Cant., No. 3334). In this specimen a blunt spicule of bone is seen on the right margin of the nasal aperture.

character is almost nil. Nevertheless it is not a little remarkable that the three most pronounced examples should have originated in a small island like Kwaiawata. But, so far as my observations go, they only allow me to remark that the occurrence is most frequent among the Oceanic negroes.

In order to ascertain whether the matter could be further elucidated by reference to the soft tissues, I dissected the lateral nasal region in a negro (*cf.* fig. 4). For although the spicular process does not appear to me to

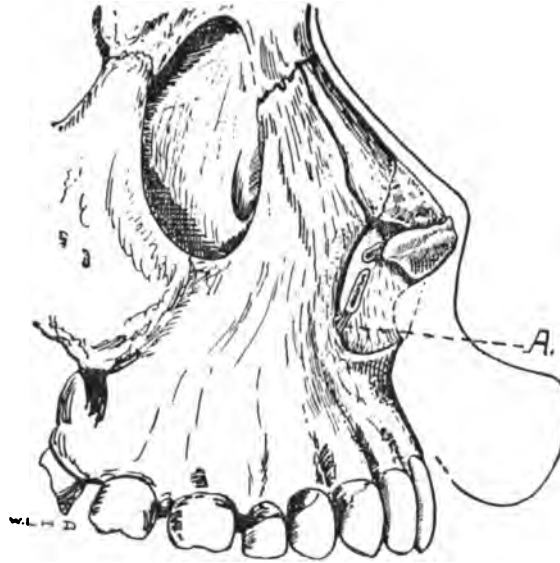


FIG. 4.—Dissection of the nasal cartilages in the head of a male negro (Krooman). The fibres of attachment of the larger sesamoid cartilage to the nasal margin are indicated in the margin of the drawing. "A," fibrous bands whereby the larger sesamoid cartilage is attached to the margin of the apertura pyriformis nasi.

represent any part of the premaxilla, I thought that it might possibly have originated in an extension of ossification into one of the small cartilages of the nose.

The dissection (fig. 4) showed that though in the negro (and the statement is found to be applicable to Europeans as well) the larger sesamoid cartilage is not in contact with the nasal margin, yet it is attached to the latter by fairly definite fibrous strands at its lower end: so that the observed effect of a spicular process would be produced if ossification were to extend into these strands.

It must be admitted, however, that the position of the strands was shown by a second dissection (though, in the second case, of a European; *cf.* fig. 5) to be variable, whereas the position of the spicular processes is fairly constant. The second dissection showed, moreover, that other fibrous strands (not represented in the figure) in the position of the spicules run more nearly along the edge of the maxilla, so that in some instances the effect may be produced by the extension of ossification into these.

In the absence of further information the anomaly seems worth recording, and it forms a rather interesting contrast with one already

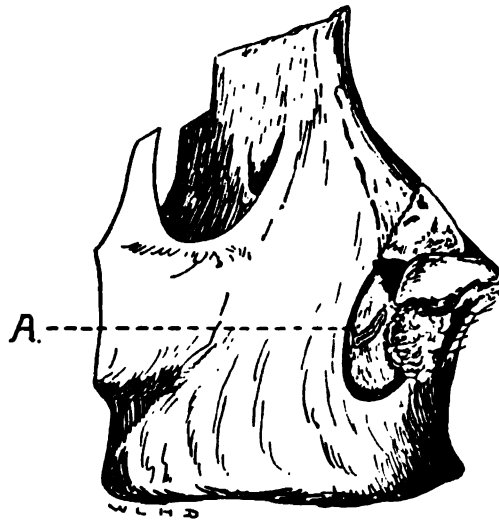


FIG. 5.—Dissection of the lateral nasal cartilages in the beak of an aged European. A, fibrous bands attaching the (single) sesamoid cartilage to the margin of the apertura pyriformis nasi.

described by me in the *Journal of Anatomy and Physiology*, vol. xxxvi., April 1902.

The skull (No. 133) is further remarkable for possessing a large dental rudiment in the right upper jaw, between the premolar teeth, on the labial aspect of the alveolar margin (*cf.* Duckworth and Fraser, *Proc. of the Camb. Phil. Soc.*, 1900). The tympanic bones are also curiously notched.

Nos. 137 and 139 are plagiocephalic (or asymmetrical). The former, though adult, has only two molar teeth in the upper maxilla on each side.

No. 106 is a senile specimen: prognathism is very pronounced and the forehead retreats very rapidly. The external pterygoid plates are of enormous size and fenestrated.

PARTIAL DEFICIENCY OF THE PERICARDIUM.¹

By ARTHUR KEITH, M.D.

IN the Museum of the London Hospital Medical College there is a specimen showing a wide natural deficiency in the left half of the pericardium. It was described in the *Transactions of the Pathological Society of London* in 1839 (vol. xii. p. 222), by Curling, and this specimen, with four others, were all that were known to Peacock in 1866, when he published his work on *Malformations of the Human Heart* (2nd edition). The lesion gives rise to

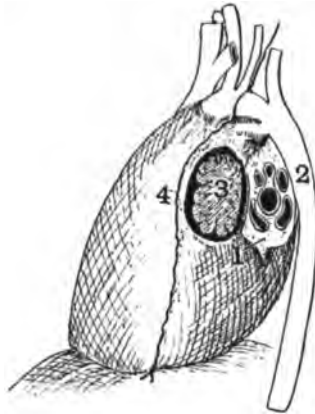


FIG. 1.—Pericardium of heart of an anencephalic fetus showing a patent plouro-pericardial foramen.

- 1, Root of left lung. 2, Descending aorta.
- 3, Left auricle protruding through foramen.
- 4, On pericardium in front of the phrenic nerve.

no symptom during life. The deficiency is always found on the left side, and in these cases the phrenic nerve is found to descend behind the costal cartilages parallel with and quite close to the internal mammary artery. The mediastinal aspect of the left lung lies directly on the heart.

When I first came across these cases I completely failed to explain the condition of parts on an embryological basis, but quite recently I discovered the explanation while dissecting a group of malformed fetuses. In an anencephalic full-time child there was a deficiency in the left side of the pericardium, through which the left auricular appendix protruded (fig. 1). The opening had a rounded, smooth margin, and was bounded behind by

¹ Read before the Anatomical Society of Great Britain and Ireland, March 1906.

the root of the left lung (see fig. 1); in front of the foramen, on the pericardium, descended the phrenic nerve. The opening is clearly a patent pleuro-pericardial foramen.

In another fetus, which was the subject of a number of malformations, there was a large deficiency of the pericardium on the left side. On removing the sternum and costal cartilages, a strong fibrous membrane was found behind them on which the phrenic nerve descended. This fibrous membrane was found to be the pericardium. In the figure a great part of it is

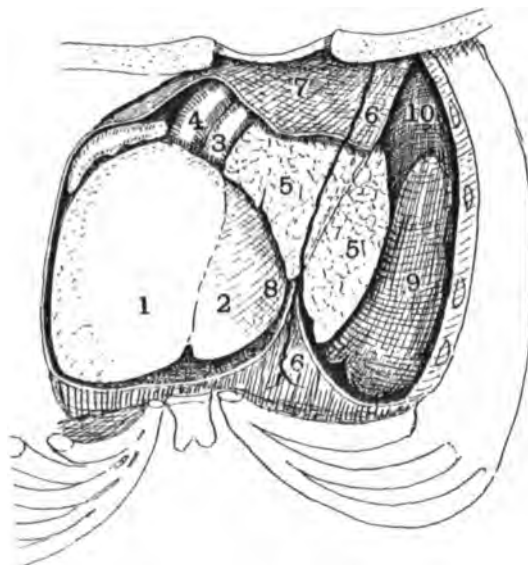


FIG. 2.—Thorax of a malformed fetus from which the sternum and cartilages have been removed. The heart and lungs have been exposed by the removal of the anterior wall of the pericardium.

1, Right ventricle; 2, left ventricle; 3, pulmonary artery; 4, aorta; 5, left lung; 6, phrenic nerve; 7, upper part of pericardium; 8, junction of pericardium with pleura at the lower margin of the greatly expanded pleuro-pericardial opening; 9, liver; 10, stomach. Both of these organs lie in the left pleural cavity, there being a wide pleuro-peritoneal communication.

shown as cut away, to expose the heart and half of the left lung which lay behind it. The left margin of the membrane descended in front of the lung and turned backwards at the lower margin (see fig. 2, 8). The greater part of the left pleural cavity was occupied by the liver, stomach, and spleen.

It was evident that the condition of parts had been produced by the lung bud growing within and expanding the communication between the pericardium and pleura, for that communication lies immediately ventral to the point at which the lung bud appears. The condition should be described as dilatation of the pleuro-pericardial foramen.

THE HISTOGENESIS OF NERVE FIBRES: A CYTOLOGICAL
STUDY OF THE EMBRYONIC CELL-NUCLEUS. By JOHN
CAMERON, M.D. Edin., D.Sc., *Carnegie Fellow, Senior Demon-
strator of Anatomy, University of Manchester.*¹

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(1) LITERATURE.

THE study of the mode of development of nerve fibres appears to have been first undertaken by Remak (60). A few years later Bidder and Kupffer (11), working in collaboration, were in a position to confirm Remak's main conclusions. These three observers furnished us with the first real attempts to give a clear conception regarding the histogenesis of nerve. Their results, owing to the unsatisfactory methods of histological technique at their disposal, are, however, decidedly different from those in general acceptance at the present day. Remak confined his attention chiefly to a study of the developing nerve fibres, while Bidder and Kupffer were successful in identifying the latter as processes of nerve cells.

These papers do not appear to have aroused much attention. Widespread interest in the question of nerve genesis was, however, revived in 1868 by His (29). He formulated the view that motor nerve fibres take origin as axis-cylinder processes from nerve cells situated within the central nervous system, and gradually grow from there towards the periphery, until they ultimately reach their end-organ. These hypothetical views were not confirmed by actual observation till several years later, when His (30 *et seq.*) demonstrated that in the human embryo the axis-cylinders or axons are processes of neuroblasts, and was thus enabled to give substantiation to his earlier suggestions.

¹ Read before the International Congress of Anatomy, Geneva, 1905.

Kölliker's almost contemporaneous work (42) on this subject agreed with that of His in regard to all the main issues. These two observers may be considered to have been the founders of what is now termed the *central theory of nerve origin*, while Balfour's work appears to have been the first important evidence brought forward in support of the *peripheral theory of nerve origin*.

Balfour (3 and 4) investigated in Elasmobranch embryos the development of the spinal ganglia, and the mode of formation of the motor roots. He considered the latter as developing from chains of cells which grow from the antero-lateral aspect of the spinal cord. He thus regarded the motor roots as multicellular in origin, a conclusion which seemed to indicate the existence of a peripheral mode of nerve genesis in this group of fishes.

Van Wijhe (67), Dohrn (14), and Beard (6) soon added their testimony to the controversy. The two former observers paid special attention to the development of the spinal motor roots in Elasmobranchs, and confirmed Balfour's observations. Beard studied the question in Elasmobranchs and birds. His conclusions were on the whole antagonistic to the views of His and Kölliker.

More recently interest in the question has been renewed by the investigations of Bethe (10), Schultze (64), Fragnito (17), and Apáthy.¹ These observers are convinced that nerves have a multicellular origin. Bethe's work, which was conducted on the chick, was vigorously criticised by Kölliker (44), who maintained the accuracy of the central theory of nerve genesis.

It is thus obvious that embryologists are at present divided into two schools regarding the origin of nerve fibres. The first or central theory, as formulated by His and Kölliker, is the one most favoured by embryologists, while the peripheral theory has received support from Balfour and others.

It is necessary to mention here the intermediate position adopted by Hensen (27). He formulated the hypothetical view that the developing nerve centre and the end-organ (muscle or skin) are really connected together from the first. This opinion received a good deal of hostile criticism, more especially from Altmann (1), but recently Kerr (39) has demonstrated in *Lepidosiren* embryos the existence of a "nervous bridge" which connects the neural tube with the myotome in the site of the future motor root, an observation which would appear to lend support to Hensen's view.

In this relation it is also important to mention that Sedgwick (63) a few years ago pointed out that all the developing tissues of the embryo

¹ To my great regret I have been unable to consult Apáthy's paper in the *Compte-Rendu des séances du troisième Congrès international de Zoologie*; Leyden, 1896.

are connected together by means of a reticulum. Thus he shows that the neuroblasts of the neural tube are in direct continuity with the cell-elements of the surrounding mesoblast through the medium of this network. More recently still, Bernard (8) has pointed out that the cell-elements of the retina, not only those belonging to one layer but also those of neighbouring layers, are united together by a system of delicate interconnecting fibrils (protomitomic system).

The question regarding the regeneration of nerve fibres is closely related to that of their histogenesis, and it has given rise to quite as keenly contested a controversy. The central theory, namely, that new axis-cylinders grow from the central end of the divided nerve, has been the favourite one for many years, and it has recently received strong support from the researches of Langley and Anderson (46), Edmunds, Mott, and Halliburton (15), Head and Ham (23), and other physiologists; but, on the other hand, suggestive evidence in defence of the peripheral theory has been furnished by the work of Kennedy (41), Ballance and Stewart (5), Bethe (10), and Fleming (16).

(2) THE NASCENT AND THE MATURE CONDITION OF THE AXON.

In a previous communication (12) the author has adduced evidence which indicates that the material constituting the processes which pass from the cell-elements in the various layers of the embryonic Amphibian retina is, in part at least, derived from the corresponding nuclei. In the same paper it was pointed out that these embryonic nuclei exhibit striking evidence of metabolic activity, observations which support the researches of Mann (51) and Huie (37) regarding nuclear function. The former observer has shown that the nuclei of actively functioning nerve cells are centres of vigorous metabolism, consisting mainly in a using up of the chromatin elements, while Huie's experiments on *Drosophila* have helped to throw further light on this complex subject.

Held (24), Scott (65), and Holmgren (36) have demonstrated the presence of nuclear compounds in the cytoplasm of the adult nerve cell which are apparently derived from the corresponding nucleus. We are thus provided with suggestive indications regarding the existence of the products of this nuclear metabolism.

One of the first signs of metabolic activity on the part of the neuroblast-nuclei in the embryonic Amphibian retina, as indeed of the neuroblast-nuclei in all regions of the central nervous system, has already (12) been shown to consist in the ingestion by them of the yolk which abounds in the tissues of the early Amphibian embryo. This ingestion appears to be effected at a

definite pole of these nuclei, and results in an accumulation of chromatin just within the same pole. A glance at fig. 1 will demonstrate the presence of this polar aggregation of chromatic material in the retinal neuroblast-nuclei. The author has therefore termed this the "assimilative pole." This storing up of elaborated material must manifestly denote preparations for some important function which is to be exhibited later. Evidences of such a function soon become prominently displayed by these structures; for it is found, as development proceeds, that the aggregation of chromatin gradually vanishes from the region of the assimilative pole, while just outside that pole a clear, almost achromatic, material slowly makes its appearance, and in time gives rise to a small accumulation there. This new substance forms part at least of the axon rudiment, and is evidently directly derived from the temporary store of chromatin at that nuclear pole, for the period of its formation is practically concurrent with the disappearance of the latter. What apparently happens is, that the chromatin in question becomes transformed by metabolic activity into a substance which in the *nascent* condition is practically achromatic in its reaction to all stains, and is in this form given off from the nucleus. Further, the position of the aggregation of chromatin at the assimilative pole of the nucleus determines the discharge of the resulting metabolised material from that pole, which may therefore now be termed the "axon pole."

The development of the axon-rudiments of the optic nerve from the ganglionic layer of the retina may be favourably studied in Amphibian embryos. In fig. 1 the two nuclei above the letter (*a*) are lying in the future site of this layer, the various layers not being yet differentiated. The assimilative pole in both these nuclei may be readily recognised by the aggregation of chromatin. In the specimen an accumulation of a clear, practically achromatic, substance could be seen lying outside these poles. This appearance is in striking contrast with the scanty perinuclear envelope previously existing round these, as well as neuroblast-nuclei elsewhere, during the early developmental stages. From this polar accumulation a delicate prolongation could be traced towards a region where a minute bundle of faintly staining fibrils (fig. 1, *op. n. f.*) could be seen lying immediately underneath the internal limiting membrane of the retina. It will also be observed that the upper of the two nuclei just referred to in fig. 1 has the left pole very markedly pointed, an appearance which suggests a withdrawal of some of its metabolised contents to blend with the accumulation of achromatic material lying outside that pole. The first traces of the optic nerve fibres in Amphibians are thus in the form of pale, almost achromatic, fibrils, the substance constituting which is, in part at least, a direct derivative of nuclear metabolism.

Striking collateral evidence of the discharge of this achromatic substance by these retinal neuroblast-nuclei is furnished by the mode of origin of the visual elements in Amphibians. The first signs of these, as shown in fig. 1, are in the form of clear achromatic globules which are invariably found in close relationship with the external poles of the nuclei in the external nuclear layer. This, in part at least, consists of achromatic material resulting from metabolic activity on the part of these nuclei.

This peculiar substance, which is so strikingly achromatic in the nascent condition, is discharged from the nuclei in such minute successive quantities as a rule, that it is difficult to make a satisfactory study of its various



FIG. 1.



FIG. 2.

properties. Fortunately, however, the author has been enabled (12) to study it actually in bulk in the cones of the Amphibian retina. The large clear globules which are found in the bases of these structures consist for the most part of achromatic substance derived from the nuclei of the external nuclear layer. This is given off in larger quantities than usual, and therefore tends to accumulate to form these large globules. Not only so, but very frequently in such cases the nucleus appears partially collapsed (12) owing to a sudden discharge of some of this metabolised material into the base of the corresponding cone. Bernard (7) has drawn attention to the frequent appearance of this semi-collapsed condition of these nuclei, and also considers that it is due to a sudden extrusion of their contents.

These globules, which are so decidedly achromatic when they first appear, soon become partially "chromatised," that is to say, they become more readily acted upon by both nuclear and cytoplasmic stains. This substance thus shows two distinct phases of its existence, viz.—a *nascent or achromatic* and a *mature or chromatised* phase.

A further stage in the growth of the optic nerve fibres of Amphibians is shown in fig. 2, where it will be observed that a striking change in the staining reactions of these fibres has taken place, for they are now freely acted upon by both nuclear and cytoplasmic stains. They thus exhibit the



FIG. 3.

nascent achromatic and the mature chromatised phases, exactly after the manner of the basal globules in the Amphibian cones. This chromatisation, which, like that of the globules referred to, is only partial, occurs in a longitudinal direction, and gives the individual axons a finely fibrillated appearance, thus demonstrating also the formation of the primitive fibrils. This exhibition of these two phases on the part of the optic nerve fibres¹ of Amphibians certainly suggests that they consist of some newly formed substance which does not exist in the very early developmental stages. These two phases will be found to exist also in the spinal nerves of all vertebrate embryos.

¹ A full account of the development of the optic nerve in Amphibians will be found in a recent paper by the author (13).

(3) DEVELOPMENT OF THE SPINAL NERVES IN THE FROG.

It was in the next place decided to study the question of nerve genesis in the spinal nerves of Amphibians, and, more particularly, to investigate the mode of development of the motor roots, seeing that the greater part of the controversy has been waged over the origin of these. The motor root does not appear very early in the frog embryo. There are certainly no traces of it when the spinal ganglion is well formed, as shown in fig. 3, which is from a fifteenth-day frog embryo. Here the spinal cord

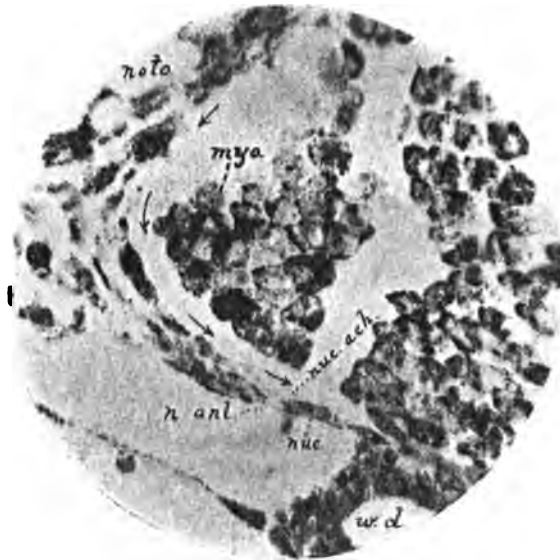


FIG. 4.

is shown with the spinal ganglion on each side; but there are as yet no signs of the motor roots. On the left of the figure is an appearance which suggests the presence of the root; but this, on carefully focussing the specimen, was found to be due to the presence of a cell-element lying close to the cord. Further, the motor root makes its appearance from the lateral aspect of the cord much further back than this (see fig. 5).

At the stage represented in fig. 3 the development of the spinal nerve itself will be found to be going on far out towards the periphery, as illustrated in fig. 4. In the latter figure the position of the nerve rudiment is denoted by the arrows. The nerve will be observed to sweep forwards by the side of the notochord (*noto*). It then takes a sudden bend in a lateral direction, and in this particular specimen could be traced outwards

behind the Wolffian duct (*w. d.*), and from thence for a considerable distance in a peripheral direction. Careful examination of the nerve at various stages by means of a $\frac{1}{2}$ oil-immersion lens showed it to consist of a row of nuclei between which a clear achromatic material makes its appearance. In that part of fig. 4 lettered *n. anl.* the presence of this pale, faintly staining substance is clearly shown. This corresponds exactly in appearance with the achromatic material already described in the optic nerve of Amphibians, and is probably, like it, a derivative of the metabolic activity of the nuclei embedded in it. It will be observed that this material forms a continuous tract with sharply defined margins. It is worthy of special note that this is formed previous to, and therefore quite independently of, both the motor and sensory roots.

A further stage of nerve genesis is illustrated in fig. 5, which shows a newly formed motor root in a twentieth-day frog embryo. It is seen to extend from the lateral aspect of the cord to the spinal ganglion. This junction of the motor root with the ganglion in Amphibia is very characteristic, the latter thus extending for a short distance along the spinal nerve, as shown also in fig. 6. The motor root is at this stage markedly achromatic, while it can be traced into the cord for a short way. It bears a striking resemblance to the substance which Kerr (40) describes as forming the rudiment of the spinal motor root in *Lepidosiren*. Careful focussing of the section from which fig. 5 was taken, as also of neighbouring sections, showed that this achromatic material could be traced to the neuroblast-nuclei in the spinal cord. Note the sharp bend at the point where the root emerges from the cord, and the commencing fibrillation near its lower margin, which imparts a very sharp outline to this portion of the root. Note, further, the absence of mesoblast tissue round the motor root in the frog. Thus it appears to be wholly developed centrally from the cord, and it blends later with the material which has been already described as forming the spinal nerve trunk itself. A similar process of blending occurs between the nerve rudiment and the spinal ganglion, and in this manner the complete nerve is formed. Thus a process takes place similar to that already described (13) in the case of the optic nerve in Amphibians, and, further, one can define fairly accurately how much of the motor trunk is formed *centrally* and how much *peripherally*. Stated briefly, the whole of the motor root arises centrally, while the trunk of the nerve is developed almost simultaneously, but, if anything, rather earlier, from the peripheral structures. Harrison (22) has shown that section of the spinal motor roots in Amphibian embryos is followed by the formation of new axons from the spinal cord, thus affording experimental proof of the central origin of these roots.

Chromatisation occurs simultaneously all along the nerve rudiment just as in the optic nerve. A reference to fig. 6 will show the appearance of the motor root after this process is well advanced. This root is shown on both sides in fig. 6, and is extremely slender. On the right side a cell-structure may be seen in close contact with the motor root. This was, however, found to be a nucleated blood corpuscle lying in a small blood vessel on the surface of the cord. It may be noted that the motor root is quite free from mesoblast tissue at this stage.

It will now be observed how closely the phenomena observed in association with the development of the spinal nerves agree with those



FIG. 5.



FIG. 6.

already described in the case of the optic nerve of the frog. The existence of the achromatic phase of the nerve rudiment, followed by its chromatised phase, is thus quite as prominent a feature of the spinal nerves as it is of the optic nerve.

(4) DEVELOPMENT OF THE SPINAL NERVES IN THE CHICK.

The histogenesis of the spinal nerves was next studied in the chick as representing a different class of vertebrate. As in the frog, the motor root appears comparatively late in the chick. Fig. 7 shows the condition of the spinal cord and spinal ganglion, and the relation of the surrounding mesoblast at the fiftieth hour of incubation. Part of the large spinal

ganglion is seen, as also the sharply defined external limiting membrane of the spinal cord, which so distinctly maps it off from the neighbouring mesoblast, the latter consisting of the usual stellate cells with their scanty cytoplasmic processes. In no section of this series could any evidences of the motor root or of the spinal nerve itself be found. Here, then, appeared to be a favourable opportunity for ascertaining the exact mode of origin of the motor root.

There has been a good deal of speculation regarding the primary origin of what appears in fig. 7 to be simply mesoblast tissue. Whatever its ultimate origin may have been, it has now become peripheral tissue, and

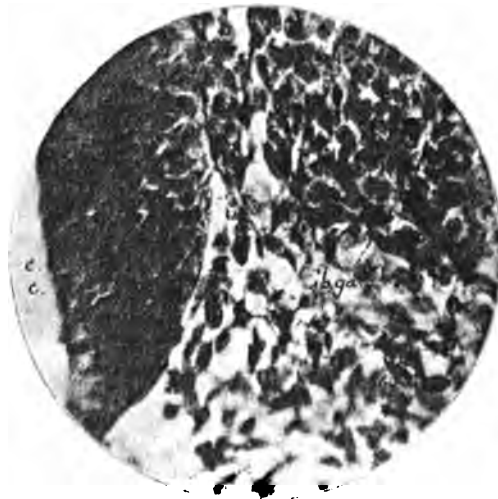


FIG. 7.

this does not in the least affect the question as to whether the nerve is formed uni- or multi-cellularly.

On proceeding a step further in development, it was found that the motor root soon began to manifest itself; for fig. 8 is taken from a chick at the sixtieth hour of incubation (*i.e.* only ten hours after the stage shown in fig. 7), in which may be observed free evidence of the presence of this structure. The first sign of commencing development of the motor root (and this is the crucial point of the whole question) is a free mitosis of the nuclei of the mesoblastic cell-elements along its future site. Fig. 9 is a much more highly magnified view of the motor root represented in fig. 8, and in this can be seen a mitotic figure. The latter structures are very plentiful at this early stage in all the spinal motor nerve roots, and

it is of further interest to note that the separation of the two daughter nuclei is always in the line of the nerve (fig. 9). Concurrently with the multiplication of these nuclei, they become surrounded by an abundant clear material which is different in appearance from the scanty cytoplasm which previously enclosed them, and is probably a derivative of the metabolic activity of these proliferated nuclei, just as in the optic nerve (13) and spinal nerves of the frog. This material, a considerable proportion of which is possibly set free during mitosis, is rather more amenable to the action of stains than in the frog. In fig. 9 the spinal cord will be



FIG. 8.

observed to have become separated from the peripheral tissue by a distinct interval, an appearance which makes the laying down of the nerve rudiment in the latter tissue much more striking.

Concurrently with the development of the motor root, a similar process is being actively carried on far out towards the periphery, the result being that the whole length of the nerve rudiment appears to be simultaneously laid down in mesoblast tissue. The multiplication of nuclei, together with the gradual appearance round them of this clear substance, could thus be readily observed "all along the line." Fig. 10 shows the changes in the mesoblast tissue to form the nerve at a considerable distance from the spinal cord. It is taken from the same embryo as figs. 8 and 9. A small portion of the myotome is shown on the right, while running parallel to it

is seen the developing spinal nerve. Here again the nerve rudiment will be observed to consist of proliferated nuclei separated from one another by material in which signs of commencing fibrillation may be observed here and there. This simultaneous development of the nerve along its whole extent is thus strongly suggestive of the peripheral mode of formation.

Concurrently with this peripheral formation, the axons of the motor roots are being developed within the spinal cord in a manner exactly similar to that already mentioned in the frog. It is not proposed to deal with these central changes in this paper, more especially as they are to form

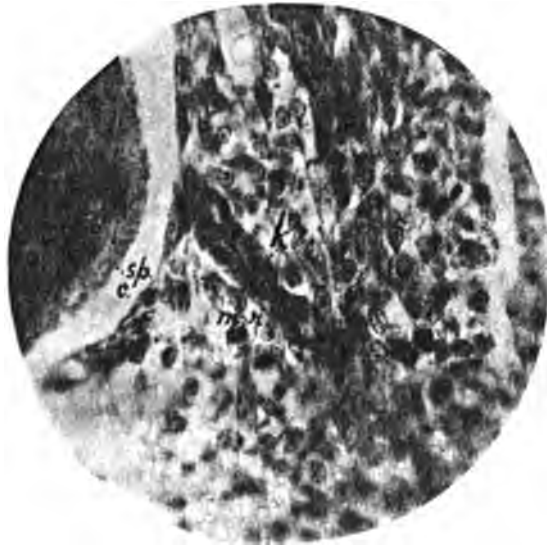


FIG. 9.

the subject of a separate communication. Thus, just as in the optic and spinal nerves of the frog, we have here a continuous tract of material extending from the central nervous system towards the periphery. In this the *future* axons are laid down by the usual process of chromatisation (see fig. 11), and here, as in the frog, the undifferentiated portion of the substance, which still remains as an envelope for each axon, may probably give rise to the medullary sheath, while the nuclei remain as the nuclei of the nerve sheath.

Whenever chromatisation is completed, the resultant is a system of axons extending from the central nervous system out to the periphery. In fig. 11 one can with ease trace the chromatised axons from the anterior cornu

through the white matter of the cord, and so on along the spinal nerve. This figure is taken from a fifth-day chick. By this time the axons take on stain freely, and are thereby very readily demonstrated.

(5) THE MODE OF REGENERATION OF NERVE FIBRES COMPARED
WITH THAT OF THEIR NORMAL DEVELOPMENT.

The question of the regeneration of nerve fibres is so closely associated with that of nerve genesis, that it was felt necessary to make an investiga-

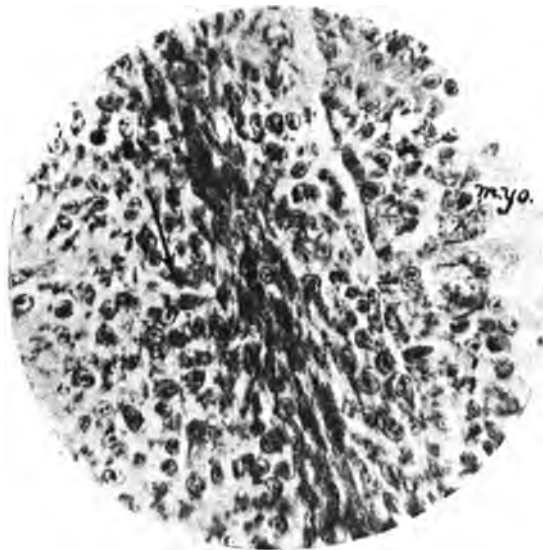


FIG. 10.

tion as to whether the appearances found during the regeneration of nerve could be observed to correspond in any way with those which exist during normal development. For this purpose Dr R. A. Fleming very kindly granted me the privilege of examining his specimens illustrating the regeneration of nerve fibres after peripheral neuritis. This observer's work (16) shows that there are strong grounds for believing that the peripheral mode of regeneration is greatly in evidence in this condition. Dr Fleming employed a modification of Stroelbe's stain, which was found to have a powerful colouring effect on the axons. Fig. 12 (taken from one of Dr Fleming's preparations) represents a longitudinal section of the regenerating ulnar nerve from a case of peripheral neuritis. A little above

the centre of the figure will be seen a deeply stained portion of a regenerating axis-cylinder (*chr. ax.*). Somewhat below and to the right of this will be observed a cell-nucleus (*nuc.*), from one pole of which a pale, almost achromatic, wavy process may be observed to extend (*achr. ax.*). I consider this to be the nascent achromatic substance which has not yet undergone the process of chromatisation, so that it is so far unaffected by the Stroebe. The achromatic and chromatised phases of the regenerating axon are therefore very similar to those of the embryonic condition.

There thus exists a remarkable analogy between the regeneration of

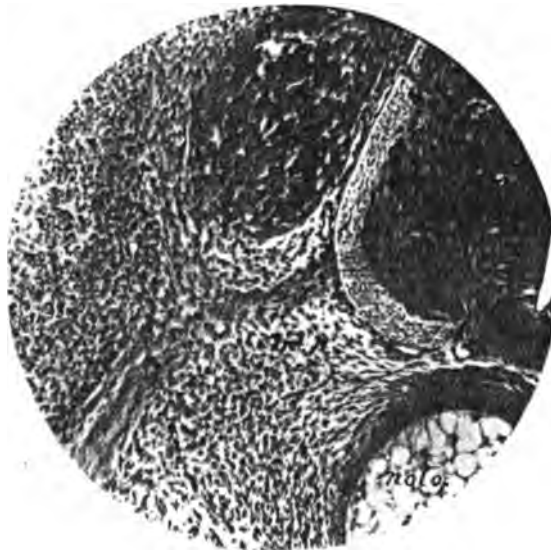


FIG. 11.

nerve fibres and the normal development of these structures, as observed, for example, in the chick. There is in both instances a marked multiplication of the nuclei along the line of the nerve, so that evidently these structures must play some very important part in nerve genesis. That this is really so, is very soon proved by what follows, for these proliferated nuclei actively metabolise, and form a comparatively achromatic material which undergoes a process of chromatisation. Further, this chromatisation occurs in both instances always in a longitudinal direction, and also appears almost simultaneously along the whole extent of the nerve, the complete continuity of the axis-cylinder being in this way established or re-established as the case may be.

(6) GENERAL REMARKS.

The observations chronicled in this paper serve to indicate that nerve fibres are not formed from one but from several cell-elements, so that we have evidently to deal here with a *combination* of the *central* and *peripheral* modes of origin. The substance supplied both centrally and peripherally is a product of specific nuclear metabolism, which imparts to it its *specific* characters, the *mature* axon being laid down in this by a process of chromatisation. In this relationship it ought to be noted that a *fully developed and deeply staining axon can never be seen to grow out from the central nervous system; and, moreover, the growing end of a somatic nerve has never yet been described.*

Whenever the mature axons become formed, they are sharply marked off from the nuclei of the nerve rudiments, so that their previous important relationship to these becomes markedly disguised; in fact, they now appear to have no association whatever (fig. 11). Professor von Lenhossek, with whom I discussed the question of nerve genesis, drew my attention to the fact that the axons are always quite distinct from the nuclei of the nerve *Anlage*, and therefore appear quite independent of these. I admit that this is certainly so after chromatisation is completed, but not in the early stages, as explained above.

Probably a great deal of the difficulty in obtaining a correct interpretation of the histogenesis of nerve has been due to the non-recognition of the mature and primary origin of the substance from which the axons are formed. His (31) describes deeply staining axons as emerging from the central nervous system, and they appear so in his numerous drawings. I wish to again point out that these in all the vertebrate types examined were found to be comparatively achromatic in character at their first appearance (see fig. 5).

It is obvious that the mode of formation of the neuron as described in this paper must result from elements which are both epiblastic and mesoblastic in nature. This conclusion is decidedly different from the acceptation that nervous tissue is exclusively epiblastic in origin. The three-layered condition of the early embryo has been vigorously insisted upon for many years, and, further, one has become accustomed to define certain tissues and organs which arise from each of these three primary layers. The cell-elements constituting each of these layers appear to present exactly the same character, so that it is somewhat difficult to comprehend how it is that organs possessing absolutely different functions are developed from the same layer (witness the epithelium of the lung alveoli and the pancreas). It is probably much better to regard the

developing embryo as a homogeneous whole, somewhat after the idea of Sedgwick, and to consider the specificity of structure and function which is imparted to the cell-elements of the various tissues as being produced by specific nuclear metabolism.

A great deal of discussion arose at one time between the various upholders of the central and peripheral theories of nerve genesis regarding the existence of cell-structures in the nerves. Balfour (3 and 4), Dohrn (14), Van Wijhe (67), and Bethe (10), for example, showed that the spinal motor roots are full of cell-elements; while His (31) and Kölliker (42) declared that the axons are at first free from nuclei, the latter growing in



FIG. 12.

amongst these from the surrounding tissues. When one comes to analyse these results it is found that the different observers are all materially correct in their opinions. For the first four made their investigations on embryos of fishes and birds, in all of which the motor roots are full of nuclei. On the other hand, His and Kölliker were also correct, for His's observations were made chiefly on human embryos, in which the motor roots are at first decidedly free from nuclei, while Kölliker's results were the outcome of a study of Amphibian embryos, and it has been shown above that the motor roots of frog embryos are at their first appearance absolutely devoid of cell-elements (figs. 5 and 6).

This research forms part of a programme of work undertaken under the terms of tenure of a Carnegie Fellowship. It was begun in the

Anatomy Department of St Andrew's University, and completed in the Anatomy Department of the University of Manchester. To both Professor Musgrove and Professor Young I wish here to convey my best thanks for many valuable facilities granted during the progress of the work, as also to Dr Gustav Mann for much kindly help and criticism. I desire, further, to record my gratitude to Dr Noël Paton for the liberal use of the microphotographic apparatus at the Royal College of Physicians Laboratory, Edinburgh, and also to Mr E. Watson for preparing the series of microphotographs from which the figures (with the exception of No. 4) have been reproduced. The latter figure I owe to the skill of Mr Richard Muir. To Dr R. A. Fleming I am deeply indebted for the use of the section from which fig. 12 was reproduced. The expenses of this research and the cost of reproducing the illustrations were defrayed by a grant from the Executive Committee of the Carnegie Trust.

(7) SUMMARY AND MAIN CONCLUSIONS.

1. The material which constitutes the axon rudiments of the optic nerve and the motor roots of the spinal nerves in Amphibians and the chick is a product of the metabolic activity of neuroblast-nuclei situated in the retina and spinal cord. This material when first formed, that is to say, in its *nascent* condition, is practically achromatic in its behaviour towards staining agents.

2. Simultaneously with the formation of these, the nuclei along the whole site of the future nerve proliferate, and at the same time become separated by a clear substance which appears to be a metabolic product from these also.

3. In this manner a complete tract of achromatic material is formed, which extends from the nerve centre towards the periphery (or from the retina towards the brain in the case of the optic nerve) and constitutes the nerve germ.

4. This material, wherever situated, undergoes a characteristic process of partial chromatization, in virtue of which it becomes much more readily influenced by staining agents. This transformation occurs almost simultaneously along the whole nerve.

5. This chromatization in the case of nerve occurs always in a longitudinal direction, and gives rise to the fully formed axis-cylinders of the adult nerve. The individual axons also exhibit a fine fibrillation, and thus we obtain an explanation of the origin of the ultimate fibrils. The achromatic material in the nerve rudiment becomes only partially chromatized, the result being that each axon remains enveloped in a thin layer of

undifferentiated substance which probably gives rise to the medullary sheath, while the ultimate fibrils likewise remain embedded in non-chromatized material.

6. A great deal of the difficulty with regard to the histogenesis of nerve fibres has been due to a non-recognition of the nature and primary origin of the material which gives rise to the axons, and imparts to them their specific characters.

7. The results of this investigation possess some interest in relation to the great controversy which at present exists regarding the question of nerve genesis; for the nerve fibres in all the types examined were found to be formed by a *combination* of the *central* and *peripheral* modes of origin.

8. The present research has also a bearing on the much-discussed neuron doctrine; for it serves to indicate that the neuron is a composite structure, *i.e.* multicellular in nature, both during the embryonic and the adult condition. The cell-elements of the nerve-fibre sheath ought thus to be regarded as an essential part of the neuron. They probably play some part in its nutrition, as evidenced by the behaviour of their nuclei during regeneration.

9. The various stages of the development of nerve fibres detailed in this paper bear a striking resemblance to those found during peripheral regeneration of nerve (Fleming). Thus there is in both instances a proliferation of nuclei, succeeded by active metabolism which results in a free discharge of nascent achromatic material, the latter substance becoming subsequently chromatised.

10. Some of the results of this research serve to assign to the nucleus a position of the highest morphological and physiological importance. They confirm the observations which the author has already made in a previous paper on the neuroblast-nuclei of the developing retina. The cell-nucleus is a well-recognised centre of metabolic activity, the latter property being a specially prominent feature of embryonic nuclei. The primary product of metabolism in the neuroblast-nuclei consists of an achromatic substance. I have already (12) termed this the *nuclear achromatin function*, and it appears to be very widespread throughout the tissues of the embryo. It is intended at a future date to bring forward evidence of its existence in structures other than those in relation to the central nervous system.

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EXPLANATION OF FIGURES. ABBREVIATIONS.

<i>achr.</i> ax. achromatic axon.	<i>myo.</i> myotome.
<i>ant. root.</i> anterior root of spinal nerve.	<i>noto.</i> notochord.
<i>a.r.</i> anterior root of spinal nerve.	<i>nuc.</i> nucleus.
<i>cent. can.</i> central canal of spinal cord.	<i>nuc. achr.</i> nuclear achromatic substance.
<i>c.c.</i> central canal of spinal cord.	<i>op.n.</i> optic nerve.
<i>chr. ax.</i> chromatised axon.	<i>op.n.f.</i> optic nerve fibres.
<i>i.l.m.</i> internal limiting membrane.	<i>sp.c.</i> spinal cord.
<i>k.</i> karyokinetic figure.	<i>sp.ga.</i> spinal ganglion.
<i>lens</i> crystalline lens.	<i>W.d.</i> Wollian duct.
<i>m.r.</i> spinal motor root.	

All the microphotographs were taken with the $\frac{1}{2}$ oil-immersion lens except figs. 3, 6, 8, and 11, which represent somewhat lower powers of magnification. They were prepared from sections stained with iron-alum-haematoxylin.

Fig. 1. The two nuclei above the letter (*a*) are situated in the site of the future retinal ganglionic layer. A little to the left of these two nuclei a thin layer of delicate optic nerve fibres may be observed lying close to the internal limiting membrane (*op.n.f.*). Observe also the first rudiments of the visual elements in the form of clear achromatic globules lying close to the external poles of the nuclei in the external nuclear layer. Retina of the 19th day frog-embryo.

Fig. 2 shows the passage of the optic nerve fibres from the ganglionic layer through the retinal wall, and so on towards the brain. Frog-embryo at the 21st day.

Fig. 3. A transverse section of the spinal cord of a 15th day frog-embryo. Note firstly its relation to the large notochord; also the two spinal ganglion rudiments on either side. As yet there are no traces of the motor roots.

Fig. 4 shows the spinal nerve rudiment in a frog-embryo at the same date as that in fig. 3. The arrows are placed alongside the developing nerve, and have their points directed towards the periphery. The nerve will be observed to course forwards by the side of the notochord, and then bend sharply outwards round the myotome and behind the Wollian duct.

Fig. 5. The motor root has now made its appearance in the form of a clear achromatic substance. 20th day frog-embryo.

Fig. 6 shows chromatisation of the motor roots. 30th day frog-embryo.

Fig. 7 shows the condition of the spinal cord, spinal ganglion, and surrounding peripheral tissue in a 50th hour chick. No traces of the motor root.

Fig. 8 from a 60th hour chick. The motor root is now developing.

Fig. 9 is a more highly magnified view of the motor root shown in fig. 8. Note the mitotic figure and the perinuclear material.

Fig. 10 is from the same embryo, and shows active formation of the spinal nerve itself far out towards the periphery. The arrow is pointing in the latter direction.

Fig. 11 shows chromatisation of the motor root and spinal nerve in a 5th day chick.

Fig. 12. Longitudinal section of regenerating ulnar nerve in peripheral neuritis. Achromatic and chromatised phases of the axon are shown.

Note.—The aggregations of chromatic material at the assimilative poles of the neuroblast-nuclei in fig. 1 have not reproduced well, owing to a general blurring of the nuclear structure. Great difficulty was also experienced in securing a successful reproduction of the achromatic material in figs. 1, 4, 5, and 12.

NOTES ON THE ANATOMY OF AN EUNUCHOID MAN¹ DIS-
 SECTED AT THE ANATOMY SCHOOL, CAMBRIDGE, DURING
 1905. By W. L. H. DUCKWORTH, M.D., *University Lecturer in
 Physical Anthropology, Cambridge.*

THIS subject is a tall, obese male (fig. 1), shown by the appearance of the external genitalia to be eunuchoid. The following notes have been made on this case.

(a) *Age returned as 87.*

(b) *General External Features.*—As mentioned above, the body is obese; the hair of the head was white, as is to be expected at the advanced age of the subject. The countenance is absolutely glabrous, and no appearances of the epidermis give any indication that the subject had ever shaved. The torso is remarkably feminine in appearance in its lower parts, but the breasts are not unduly developed. A small warty tubercle, 200 mm. below the left mamma and vertically in line with it, may be an accessory nipple.

The suprapubic fat is so abundant as to produce an eminence in this region which simulates the mons veneris of the adult female. The pubic hair is scanty (*cf.* fig. 2).

The penis and scrotum are extraordinarily diminutive; the former is not completely covered by the prepuce; it measures 36 mm. in length in the retracted condition, and the glans is small. The organ resembles that of the anthropoid apes.

The scrotum is correspondingly small and the raphe inconspicuous. At first no testicles were detected, but subsequent examination revealed their presence in the scrotum. For details of their conformation, *v. infra.*

The chief point of importance in connection with the limbs is the feminine feature of unusually short forearm, the radio-humeral index $\left(\frac{R \times 100}{H}\right)$ providing the very small and characteristically feminine value of 67.1. The thighs are somewhat feminine in appearance, as the adipose

¹ Subject No. 4: Lent term 1905.

deposit has masked the contours of the several muscular masses. The following measurements were made:—

Stature	. . . . .	1717 mm.
Span	. . . . .	1792 "
Arm	. . . . .	359 "
Forearm	. . . . .	241 "
Trochanter to internal malleolus	. . . . .	458 "
Tibia	. . . . .	440 "



FIG. 1.

(c) *The dissection of this subject* provided an unusual number of anomalies. The genitalia will be first considered.

The spermatic cord is present on each side, and is rather larger than usual, owing to an abundant fatty deposit. Each cord appears to end blindly in the scrotum, but dissection reveals the presence of a small testicle on each side, the dimensions being approximately 17 mm. in height, 14 mm. from before backwards, and 7 mm. in width. In each case a hydatid body

is present, and at the base of one testis an extremely hard calcified nodule of the size of a grape-stone was discovered. An epididymis is also present on each side. The processus vaginalis is continuous with the tunica vaginalis testis, so that the infantile condition is here retained. No vesiculæ seminales exist, though each vas is somewhat dilated just before its termination in the urethra.

The prostate gland is not enlarged: the appearances in the floor of the prostatic urethra are normal. The bladder wall is thickened, the prostatic

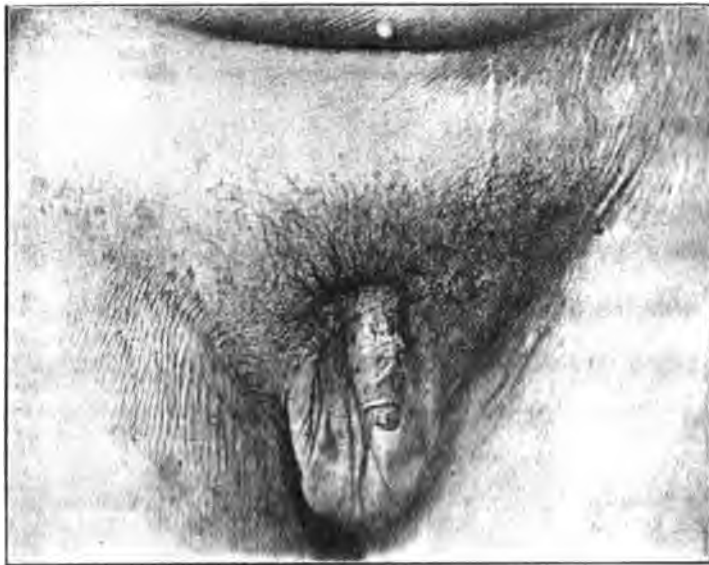


FIG. 2.

plexus of veins is enlarged and somewhat varicose. No anomaly is detected in connection with the ureteric apertures in the bladder.

The small penis has distinct though small crura, covered by a stratum of muscular fibres attached, like the crura, to the ischium and pubis.

The urethral bulb is surrounded by a representative of the *M. ejaculator urinæ*, which calls for no special comment. Portions of the testicles and prostate were removed for histological examination. As the cadaver has been prepared in the ordinary way only for the dissecting-room, the tissues are not in perfect condition for microscopic study. Nevertheless it is clear that the testicular tubules are dense fibrous cords without lumen, and containing many nuclei aggregated at their centres. Blood-vessels are fairly numerous, though rather less plentiful than in the normal subject.

The epididymes consist of tubules with thick fibrous walls, and their epithelial lining is replaced by fibrous tissue. The lumen is very small.

Sections of the highest portions of the testes show that the wall of the vas deferens is thick and fibrous; the pampiniform plexus of veins is distinct.

In the foregoing respects the testes resemble those of eunuchoid persons. The chief difference between the present case and the example described by Dr Joseph Griffiths¹ lies in the fact that fibrosis is more marked here, the subject being of an advanced age and thus contrasting with the youth of twenty-two examined by Dr Griffiths. The prostate gland appears unusually rich in fibrous tissue, with corresponding poverty in glandular elements. Herein too this case agrees with that to which reference has just been made (Griffiths, *op. cit.*).

(d) *The Skeletal System*.—The left hand provided a most perfect example of the complete independence of the os centrale carpi. The right foot is furnished with a separate and special ossicle at the proximal end (and to the fibular side) of the metatarsal bone of the hallux.

(e) *The Muscular System*.—

- (i.) The M. rectus abdominis presented four tendinous inscriptions, whereof three are above the umbilicus and one below that structure.
- (ii.) In the left upper limb a muscular and tendinous slip connects the long head of the M. triceps with the M. teres major. The slip passes from the outer border of the long head of the M. triceps three-quarters of an inch from the origin of that muscle to about the mid-point of the posterior aspect of the M. teres major.
- (iii.) The M. biceps is connected by a muscular slip to the M. supinator longus.

(f) *The Nervous System*.—The cutaneous branch to the radial side of the pollex arises from the musculo-spiral nerve and traverses the M. supinator longus on its way to its destination.

The brain has not been available for examination hitherto.

(g) *The Vascular System*.—

- (i.) There is great cardiac hypertrophy; the circumference of the organ in the auriculo-ventricular groove measures 340 mm.; and the arc from this level and round the interventricular groove measures 220 mm.²
- (ii.) The right subclavian artery arises from the thoracic aorta, thus furnishing a demonstration of the morphological history of the normal aortic trunks.

¹ *Journal of Anatomy and Physiology*, vol. xxviii. p. 221.

² For this note, as well as that referring to the pancreatic ducts, I am indebted to Dr E. Barclay-Smith.

- (iii.) The right common carotid artery, as is usual when the preceding anomaly obtains, has a separate origin from the subclavian artery, and arises independently from the aortic arch in its transverse portion.
- (iv.) There is a very definite tortuosity or sigmoid flexure of the internal carotid artery of the left side, commencing at about 25 mm. above the origin of this vessel from the common carotid artery.
- (v.) In the left upper limb the posterior circumflex artery arises in common with the superior profunda artery, and reaches the back of the limb by passing beneath the *M. teres major*.
- (vi.) The internal jugular vein is pierced by the spinal accessory nerve at a level corresponding to the tortuosity of the internal carotid artery.
- (h) *Miscellanea*.—The pancreas presents the rare anomaly of concurrent existence of the two ducts (of Wirsung and of Santorini: cf. Minot, *Human Embryology*, p. 767). This constitutes the retention of a fetal condition.

Conclusion and Summary.—This is an example of arrest of the development of the external genitalia at a stage anterior to puberty. Not only have the testes failed to develop in size and structure, but they have even been subject to degenerative changes not unlike the sequels of chronic inflammation. Inflammatory changes are not unknown in the testes, as in the metastatic form of mumps (parotitis); but then, as Dr Griffiths has pointed out, the condition affects one testicle only. Here the change is bilateral.

Such imperfect development of the sex-glands, together with the lack of hair on the face, pubes, etc., constitute the eunuchoid condition. It is a variety of infantilism, and closely allied to the cryptorchid conformation.

Ammon¹ has shown that in German conscripts about 3 in 1000 (3 per cent.) possess testes of less than normal size, and therefore presumably imperfectly developed. Defective development in stature and in hirsuteness is commonly associated with such imperfections in the testes. In only one instance among nearly four thousand cases has Ammon observed the condition in an individual of really tall stature (over 1750 mm.). And Ammon further observes that whereas in some of these cases the lapse of a few more years suffices for the development to take place, yet in a few instances the arrest is permanent. The individual here described enters into this category, and hence is justifiably described as an example of the eunuchoid variety of infantilism.²

¹ O. Ammon, *L'Anthropologie*, 1896: "L'Infantilisme et le Féminisme au Conseil de Révision."

² Other important articles are as follows:—Meigs, *L'Anthropologie*, 1895: "L'Infantilisme, le Féminisme et les Hermaphrodites antiques;" Curling, Art. "Testicle" in Todd's *Cyclopedia of Anatomy and Physiology*, vol. iv. pp. 991, 992.

THE PAPILLARY RIDGES AND PAPILLARY LAYER OF THE
CORIUM IN THE MAMMALIAN HAND AND FOOT. By
WALTER KIDD, M.D., F.Z.S.

THE present communication arises out of a paper read before the Anatomical Society in February 1905 on Imbrication of the Papillary Ridges in Man. This phenomenon is found to exist in a considerable number of other Mammals, and it has been here studied in connection with the papillary layer of the corium in a large number of species. Upwards of seventy species, besides several human subjects, have been microscopically examined, and the most notable of these results, reduced to microphotographs, are



FIG. 1.—*Petrogale penicillata*. $\times 16\frac{1}{2}$. Pes D 4. Terminal phalanx; longitudinal section through coarse nodules covering closely the plantar surface, except over the heel. Groups of papillae limited to a single nodule of epidermis; intervening portions show no papillae or bands of pigment granules. These bands shown also in two species of *Macropus* and in *Epyprymnus rufescens*, and are found both in manus and pes of *Petrogale penicillata* but much less defined in manus than in pes.

here brought forward to illustrate the variations both of the papillary ridges and the papillary layer of the corium. The groups examined are Marsupials, Edentates, Rodents, Carnivores, Hyracidae, Insectivores, Chiroptera, and Primates. The sections made have been mostly from material kindly supplied by the Prosector's Department of the Zoological Society's Gardens. They have been hardened in alcohol, and cut so as to be in a vertical plane with the palmar and plantar surfaces, and, when it has been possible, at right angles to the lines of the papillary ridges. Careful note has been kept as to the direction of the imbrication of the ridges when it exists, whether

proximal or distal. It has been my endeavour to show the coarser part of the minute anatomy of the skin-structures in these varied animal forms, the outlines of the papillary ridges and papillary layer of the corium, rather than to demonstrate by delicate methods the nerve-endings and nerve-fibrils found in these structures. The individual specimens illustrating this paper have been chosen out of a large number (over 700) as being calculated best to demonstrate the exceeding variability of the papillary ridges and the papillary layer of the corium, especially the latter, and in most cases they



FIG. 2.—*Hystrix cristata*. $\times 50$. Pes. Plantar surface, pad on fibular side, section longitudinal; skin bare, showing neither scales, nodules, nor papillary ridges; papillæ low and broad.

have been chosen because of showing the most highly developed arrangements of these structures. It will be observed by a reference to the illustrations that the highest degrees of development correspond closely with the most sensitive areas of the hand and foot of the different species. In many of the illustrations the Malpighian layer of the epidermis and the openings of the sudoriparous ducts present a strongly marked row of projections into the corium, and they arrest attention more than the papillæ of the corium because of the amount of pigment contained in them, but they also serve as a useful background to show up the outlines of the papillæ beneath them.

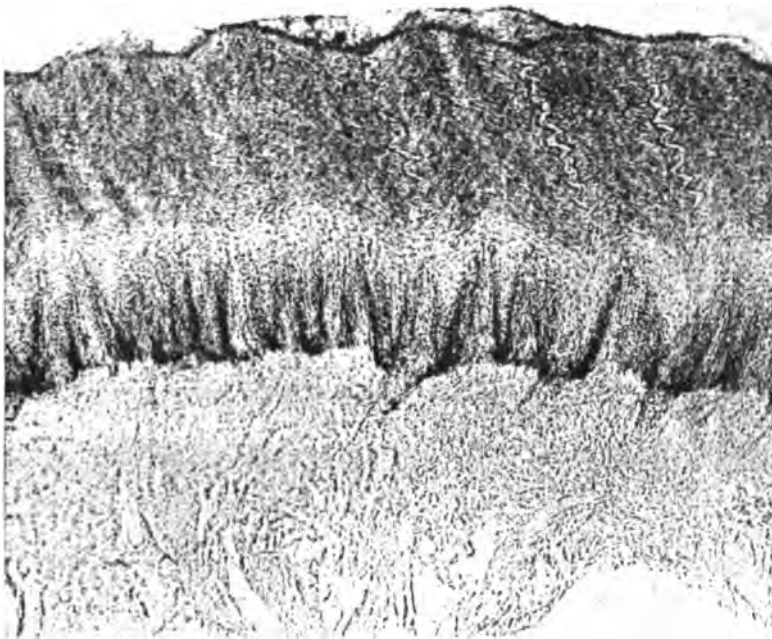


FIG. 3.—*Felis domestica*. $\times 60$. Manus. Palmar surface, central pad, section longitudinal; skin covered with rods of thickened epidermis; papillae long and sharp-pointed.

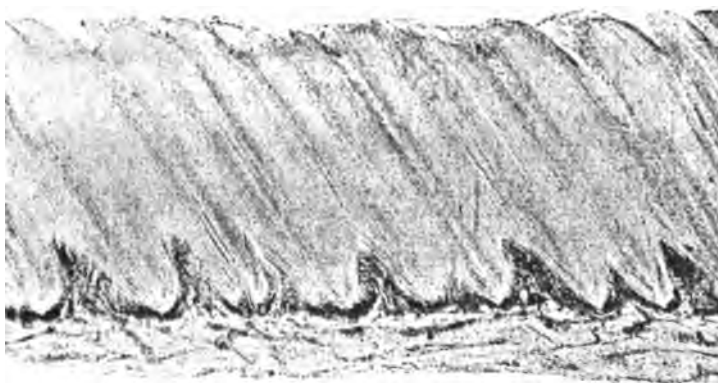


FIG. 4.—*Ursus americanus*. $\times 25$. Manus. Pad on palmar surface; very thick epidermis, arranged in rods with thickened extremities; papillae relatively small but sharp-pointed.

This particular series of illustrations is taken from forty species of mammals, and about 400 sections have been made from them. The most marked features of the individual species have been chosen for illustration, but in many of the less strongly marked sections which are not here brought forward, the results have been quite as instructive from the point of view of associated function.

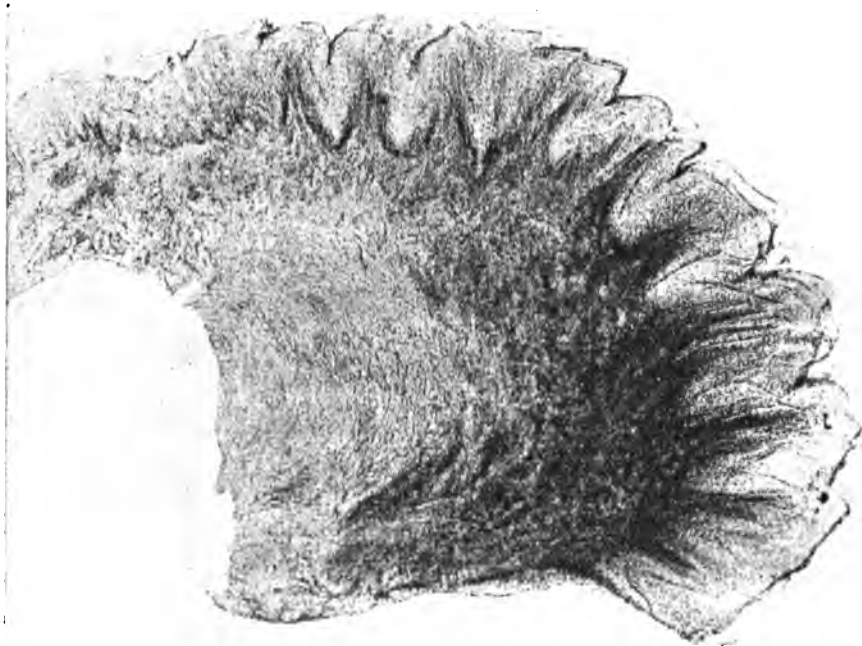


FIG. 5.—*Lutra vulgaris*. $\times 30$. Manus D 2. Terminal phalanx, longitudinal section through a group of rudimentary papillary ridges. Surface covered with scales, except at distal ends of terminal phalanges, where ridges are shown. This specimen shows that on the portion of skin covered by papillary ridges the papillae of the corium beneath them are strongly marked and long, with distal imbrication. On the left-hand portion of the section the papillary ridges are absent, and the papillae of the corium ill-developed.

Such variable results as these in several zoological groups might be classified and interpreted in several ways, but the point of view from which they are here considered is the connection of the papillary ridges and papillary layer of the corium with the sense of touch.

The pads found on the ventral surfaces of the mammalian manus and pes have been identified by such writers as Wilders, Whipple, and Schlagin-

haufen as "walking-pads," and as organs with a definite function rather than variations secondary to morphological changes. Being composed of hard fat in which much fibrous tissue is interspersed, they have clearly



FIG. 6.—*Nycticebus javanicus*. $\times 30$. Pes D 3. Terminal phalanx, transverse section. This specimen and one of *Nycticebus tardigradus* show very well-developed papillary ridges and long, pointed, closely set papillae of the corium.

the primary function of acting as "buffers" in the movements of the animal possessing them. This simple function is seen in the lower groups of Mammals, but becomes insignificant as the higher Primates are approached.



FIG. 7.—*Lemur brunneus*. $\times 25$. Pes D 3. Terminal phalanx, transverse section.

But the papillary ridges, which undoubtedly are associated with these organs in the earlier stages of development, and are always more highly developed where the phalangeal, palmar, and plantar pads are found, have been by most recent writers too much identified with the mechanical

functions which they subserve. Galton, Lydekker, Wilders, Whipple, and Hepburn all dwell much on the functions of the ridges in raising the mouths of the sudoriparous ducts, or in forming a roughened surface which will assist the prehension of objects with hand or foot; and they have exalted these mechanical functions at the expense of that which seems to me to be their primary function, viz. to increase the efficiency of the sense of touch whether in walking or in prehension. The ridges have indeed been termed "epidermic ridges," and "friction skin" is the term applied to the skin where these are found, instead of the older and, as I desire to show, more correct term, "papillary ridges." The effect of this undue importance attached to the mechanical functions of the ridges is to weaken

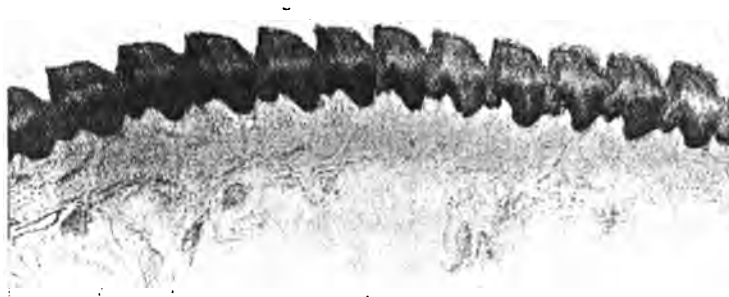


FIG. 8.—*Cercopithecus callitrichus*. $\times 25$. Manus. Palmar surface, pad on ulnar side over carpus; longitudinal section; imbrication of papillary ridges proximal; papillæ of corium bifurcated by openings of sudoriparous ducts.

indirectly the importance of the papillary layer of the corium as the essential organ of touch. This indirect influence may not be intended by the writers in question, but it exists, and one object of the present series of observations has been to show the intimate association in function between the papillary ridges and papillæ of the corium. The evidence afforded by these sections of skin in favour of the connection of the ridges and papillæ with the sense of touch, must necessarily be only anatomical, and must rest only on inference rather than direct physiological proof. From the nature of the case it is evident that delicate physiological experiments cannot be carried out on the tactile sense of wild animals, even though they be living in captivity. But a high degree of probability, amounting almost to demonstration, may, I submit, be attained from the study of the minute anatomy of the skin in these species brought forward.

A short summary of the results obtained will suffice to draw attention

to the main points. Certain of the lower groups, Marsupials, Edentates, Rodents, and Carnivores, present on the palmar and plantar surfaces, varying forms of scales, nodules, and rod-like extensions of the epidermis, and only two species out of these orders have been found with papillary ridges, and in both cases these have been distributed partially over the surfaces: these two are *Didelphys azarae* and *Cereuleptes candivolvulus*. Nevertheless nearly all these, except the few rodents examined, present highly developed papillæ of the corium; and wherever in these or higher forms the ridges are well marked, the papillæ are also well marked. It is not necessary to define what one means by a high degree of development of the papillary



FIG. 9. —*Hylobates lar*. $\times 30$. Pes D 1. Terminal phalanx, proximal end; section longitudinal.

ridges, for this is readily apprehended, but the papillæ of the corium require to be referred to particularly. There are two main types of form of the papillæ, the sharp-pointed and long type, which extend close up to the free surface of the epidermis. This is most evident in the Carnivores and in six Lemnroids examined, and in certain of the higher Primates. Another feature of this higher form of papillary development is the closeness with which the papillæ are set in some forms as compared with the widely separated arrangement in other forms. These three features, *length*, *acuteness of the angle*, and *close position*, distinguish what are here held to be high degrees of development of the papillæ of the corium. In the lower degrees of development, such as are seen in Rodents and one Insectivore and a few Primates, there are either no papillary ridges or rudimentary ones,

and the papillæ of the corium are short and flattened at their apices. These more rudimentary forms of ridges and papillæ are shown abundantly in the sections referred to at the commencement of this paper, which have been taken from species with high degrees of development in certain

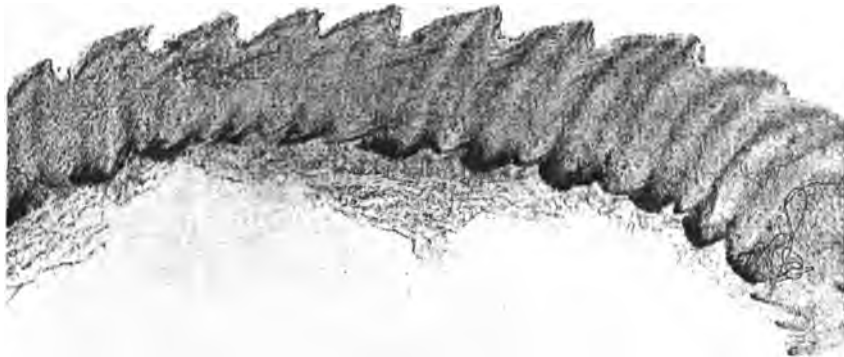


FIG. 10.—*Simia satyrus*. $\times 35$. Manus D 2. Proximal phalanx, ulnar side; section longitudinal; papillary ridges well marked; much imbricated in distal direction; papillæ of corium low and irregularly-formed.

regions, but which are themselves of lower development, and associated with areas of the palmar and plantar surfaces where the sense of touch is

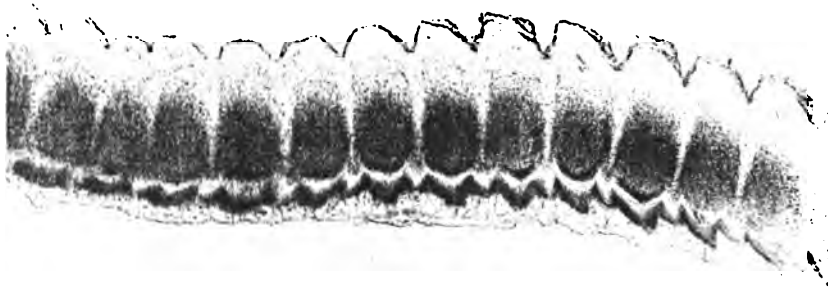


FIG. 11.—*Anthropopithecus troglodytes*. Manus. Palmar surface, pad at base of D 3, transverse section; imbrication proximal.

not prominent. These sections can only be referred to, being too numerous to bring forward as illustrations.

The group of Lemuroids, *cf.* figs. 6 and 7, may be cited as being the most striking in their degree of development, both of ridges and papillæ, of all

the groups examined. The ridges are clear cut and very regular, the papillæ very long and pointed and set extremely close to one another, and they project so much into the epidermis as to be very near the free surface. These characters suggest very clearly that in this group of animals the sense of touch is of extreme importance to them in their lives. If one bears in mind that three of them are nocturnal and arboreal, and the other two diurnal and arboreal, one can gather from these facts the great importance to them that their sense of touch should be very acute. A continual need of their arboreal lives is that they should maintain by reflex means their equilibrium, and I would suggest that in their highly developed papillary ridges and papillary layer of the corium they possess most efficient structures for the transmission of impulses to their nerve-centres



FIG. 12.—*Man.* $\times 25$. *Manus D 4.* Terminal phalanx, papillary ridges imbricated in distal direction; papillæ of corium double.

for the performance of this important function. The function here referred to, that of the reflex maintenance of equilibrium, though of immense importance to the animals in question as well as other arboreal forms such as *Didelphys azara*, is of a simple nature, and higher animal forms will necessarily require to perform tactile operations of a more complex character. These are found in their highest degrees of development in man, though, as these sections show, the general characters of the ridges and papillæ do not advance in complexity up the zoological scale. The application of the tactile sense to more complex purposes must depend more upon higher cerebral organisation than upon the peripheral anatomical structures in the hand and foot which subserve that sense. This consideration accounts for the relatively low degree of development, such as width of distance between the papillæ, and bluntness of their apices found in some of the monkeys among those illustrated, and even in the anthropoid apes.

44 Papillary Ridges and Papillary Layer of the Corium

In man the areas of the palmar and plantar surfaces of the hand and foot which show the best degree of development of the papillary layer of the corium are those where the patterns formed by the papillary ridges are most complex, viz. on the terminal phalanges. The human subjects examined have been too few to enable one to judge how far the phenomenon of imbrication of the ridges is constant, but it undoubtedly is an efficient means of increasing the acuteness of the sense of touch, as was shown in the former paper referred to on this phenomenon. Further and extensive observations on this matter are required.

ANATOMICAL NOTES. By R. B. SEYMOUR SEWELL, B.A., *Christ's College, Cambridge; Fellow of the Anthropological Institute of Great Britain and Ireland.*

I. PHALANX, POSSESSING TWO EPIPHYSES.

OWING to the kindness of Professor Macalister, I have been enabled to examine a phalanx which presented the very rare condition of possessing two epiphyses.

The bone in question was the proximal phalanx of the index finger.

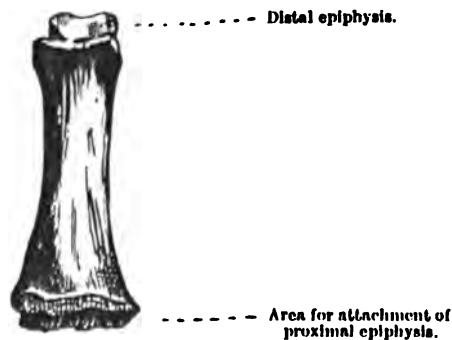


FIG. 1.—Proximal phalanx of index finger, showing an abnormal distal epiphysis.

At the proximal end of the bone was a roughened surface of somewhat oval shape—flat from side to side and slightly concave from before backwards; it had undoubtedly served for the attachment of the epiphysis, which is normally present at this end of the bone, but which, owing to non-union with the shaft, had been lost.

At the distal end the articular surface for the second phalanx was distinctly marked off from the shaft by a groove.

This groove was best marked where it crossed the palmar aspect of the bone; it was continued backwards on each side for some distance, finally almost disappearing, only slight traces being visible on the dorsal aspect.

The bone was evidently from a young subject, and one must conclude

that this groove marked the line of union of the diaphysis and an abnormal distal epiphysis.

II. AN INTERARTICULAR FIBRO-CARTILAGE BETWEEN THE ASTRAGALUS AND THE MALLEOLUS OF THE FIBULA.

So far as I am aware, the existence of such an interarticular cartilage has never been previously described.

In the specimen which I have been able to examine, the cartilage was roughly triangular in outline, having the apex downwards, and presented a delicate free margin above.

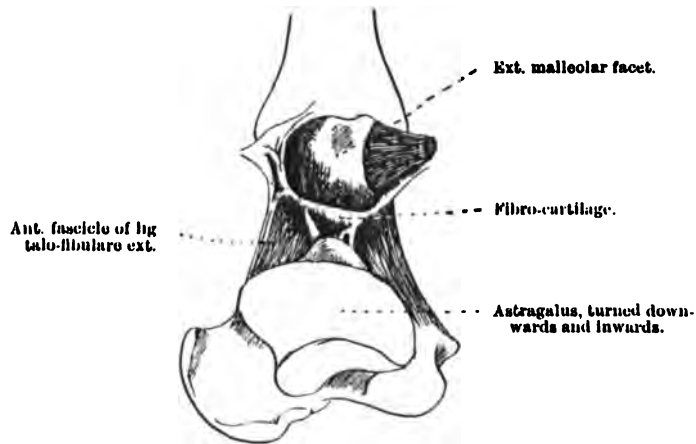


FIG. 2.—Showing position of interarticular fibro-cartilage in ankle-joint.

It intervened between the apex of the processus lateralis tali and the lower portion of the external malleolus.

The cartilage was completely covered on its two sides by synovial membrane, delicate strands of which also ran from it to the various neighbouring structures; thus above and in front a narrow though strong band of tissue connected its anterior angle with the anterior fasciculus of the ligamentum talo-fibulare externum, and from this point was continued upwards and then backwards to end finally by blending with the ligamentum tibio-fibulare inferius: this latter portion formed a narrow fold projecting into the joint cavity.

The rest of the anterior border of the cartilage was very considerably thickened, and was quite free, not being connected with the capsule of the

joint in any way. The apex of the interarticular cartilage, as already mentioned, pointed downwards, and was firmly attached to the (ligamentous) joint-capsule; while along its posterior border the synovial membrane was reflected off it on to the various neighbouring structures, and one or two small synovial strands connected it with the *processus lateralis tali*.

The presence of such an interarticular cartilage is of some morphological interest, since it occupies in the angle-joint a position exactly comparable with that occupied by the fibro-cartilage normally present in the wrist-joint.

III. LAMELLÆ IN FETAL ASTRAGALUS.

While working on the astragalus, I cut sections of its cartilaginous precursor in the feet of several fetuses of different ages, and in one of them I came across a condition that seems worthy of some description.



FIG. 3.—Section of a sixth month fetal astragalus (from a microphotograph), showing the arrangement of the fibrous bands.

The fetus was about the age of six months, since the testes were situated at the internal abdominal ring, and the *os calcis* had just commenced to ossify, there being no ossific nucleus in the astragalus itself.

The cartilage of the astragalus was of a very vascular character, this condition being especially marked in the corpus.

In the hyaline cartilage bands of some denser material could be seen; these seemed to be of a fibrous character, for, like all fibrous tissue, they possessed a special affinity for Rubin S. stain. The bands were arranged in two definite systems.

(1) In the body of the bone there was an irregular network of strands, and starting from this was a series of well-marked bundles, which ran forward through the neck to the caput.

(2) A second series of bundles, in the caput, were arranged almost at right angles to the previous set, and ran parallel with the surface of the *facies articularis navicularis*.

In the seventh month, when ossification takes place, the whole of this arrangement is swept away, and bony lamellæ are subsequently formed.

It is interesting to compare this arrangement with that found in the adult.

It at once becomes evident that there is a most remarkable similarity between these two arrangements; the only difference of importance being the development in the adult of a third series of lamellæ running from the trochlear facet downwards to the *facies articularis calcanea posterior*, which serve to transmit the weight of the body downwards to the heel.

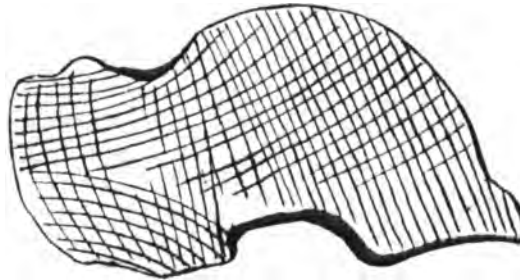


FIG. 4 —Showing the arrangement of the lamellæ in a sagittal section through the astragalus.

In the sixth month it is quite impossible that there should be any pressure on the foot externally, but the muscles of the foot will, by their traction, exercise a certain amount of traction on the phalanges and metatarsals, which will be transmitted back through the distal row of tarsal bones to the astragalus.

The muscles which will bring about this are mainly the *flexor longus digitorum* and *flexor longus hallucis* on the sole of the foot, and the *extensor longus digitorum*, and to a less extent the *extensor longus hallucis*, on the dorsum.

All hyaline cartilage, when macerated, tends to break up into bundles, which are arranged in the lines of greatest pressure, and it seems possible that some of these bundles may become hypertrophied and so give rise to the above condition.

HOUR-GLASS STOMACH. By A. E. ORR, M.D., *Demonstrator of Anatomy, McGill University, Montreal.*

THE specimen described in this paper was met with in the dissecting-room during the past winter.

It is the stomach of an elderly, well-developed, and rather tall female, and presents a typical hour-glass form with two thin-walled sacs, a larger cardiac, and a somewhat smaller pyloric connected by a cylindrical, thick-walled, constricted portion.¹

The cardiac sac measures 9.5 cm. transversely, 11.5 cm. in longitudinal direction; the pyloric sac 7 cm. transversely by 8½ cm. longitudinally; the constricted portion 3.5 cm. transversely by 4 cm. longitudinally.

The viscus was measured after being incised, emptied, and spread out flat.

There were no adhesions nor constricting bands in the vicinity of the viscus, nor is there any external appearance denoting cicatricial contraction from disease of the mucosa or wall.

The macroscopic appearance of the fibres is noteworthy. Upon the constricted portion anteriorly they are oblique and circular, whilst posteriorly they are longitudinal, reminding one of a constricted band of longitudinal fibres of the large bowel.

The lesser curvature is not involved in the constriction.

On trying to dilate the constriction by air pressure, we were unsuccessful with a force which one dare apply short of almost certain rupture. This lack of distensability may be due to the hardening of the fibres by the alcoholic and carbolic injection fluid, and by prolonged immersion in alcohol after removal from the body.

Upon incising the constriction along its upper border, we find no evidence of cicatrization nor of any pathological process. The wall is fully three times the thickness of that of the sacs. The mucous membrane is thrown into longitudinal folds which greatly encroach upon the lumen of the tube. The appearance is similar to that seen in the interior of a contracted urinary bladder or other contracted hollow viscus.

Hour-glass stomachs are not infrequently found post-mortem. This is the second one I have met with in about six hundred bodies that I have seen dissected. Others may have escaped my observation.

¹ Demonstrated at Regular Meeting, Montreal Medico-Chirurgical Society, April 20, 1906.

Authorities seem unanimously agreed that there is a definite acquired form of hour-glass stomach, the causes being cicatricial contraction following ulceration, or corrosive gastritis, traction or compression by adhesions, bands, etc., or occurring with carcinoma.

Dr J. M. Elder (1) describes a case which is particularly interesting, as he had treated the patient for ulcer of the stomach with hæmatemesis, and, twelve years afterwards, diagnosed hour-glass stomach, and relieved it by operation. The patient had suffered from persistent vomiting, with profound emaciation, but recovered completely, and is now alive and well, four years after operation.

As to a congenital form, it appears to have been generally held in Great Britain, and to a lesser extent on this continent, that there was a congenital form of hour-glass stomach; and even Riegel, in his volume in Nothnagel's *Encyclopædia*, accepts this view, although Continental European writers have usually opposed it.

In Cunningham's *Text-Book of Anatomy* (1st edition, 1902) Professor Birmingham states that there is a congenital form. But in a recent monograph (2) Professor Cunningham appears to hold the view that a congenital form does not exist. He cites much evidence to show that the different shapes found in so-called congenital hour-glass stomachs are due to fleeting or temporary contractions of larger or smaller bands or portions of the circular and oblique fibres, being merely phases of peristalsis which have become fixed in death.

A note may also be added on diverticula of the stomach.

It is well known that diverticula may be found anywhere in the course of the digestive tube, but I do not remember having seen any of the stomach.

W. F. Hamilton (3), however, describes and figures a stomach presenting a peculiar shape, and a diverticulum in the form of a pouch 2 cm. broad and 3 cm. deep, situated upon the posterior wall of the cardiac end, near the œsophagus.

Küss (4) reports a case of diverticulum of stomach, and states that he had found no previous record of such a condition. In his case the pouch was 2 cm. deep, and situated upon the great curvature 6 or 7 cm. from the pyloric valve.

REFERENCES.

- (1) *Montreal Med. Journ.*, 1903.
- (2) *Trans. Roy. Soc. Edin.*, vol. xlv., pt. i., No. 2.
- (3) *Montreal Med. Journ.*, 1901.
- (4) *Bull. et Mém. Soc. Anat. de Paris*, 1905, lxxx., 561.

A RARE ANOMALY OF THE CAROTID ARTERIES (INTERNAL AND EXTERNAL). By A. E. ORR, M.D., C.M., *Demonstrator of Anatomy, McGill University, Montreal.*

THIS anomaly occurred in a well-developed adult male. It is noteworthy from its rarity as well as from its surgical interest. A similar condition of a very low division of the common carotid, with a very small internal carotid, does not appear hitherto to have been published.

Six mm. from its commencement the right common carotid divides into a large trunk and a small trunk. The smaller division is the internal carotid, and passing upward, close to the outer side of the larger vessel, occupies the usual position above the level of the upper border of the thyroid cartilage and goes through the normal foramen and canal in the petrous portion of the temporal bone. It is very small, smaller than the vertebral, being only 2 mm. in diameter, whilst the other trunk is 7.5 mm. in diameter.

It gives off no branches in the neck, but in the cranial cavity the ophthalmic artery arises in the usual way, leaving a very small vessel proceeding to the brain.

Unfortunately the brain had been removed during the preparation of the body for dissection, and could not afterwards be identified.

No abnormal vessels were found replacing or supplementing the small internal carotid.

The other carotid trunk, much larger than the internal carotid, gives off the inferior thyroid artery at the level of the cricoid cartilage. The superior thyroid arises opposite the middle of the thyroid cartilage, whilst just above the level of the upper border of the thyroid cartilage is the origin of the superior laryngeal.

Above the thyroid cartilage the vessel continues upwards as the external carotid, without any very noteworthy peculiarities.

A thyroidea ima is present, springing from the innominate, on its inner aspect, near its termination, and sending branches to both lateral lobes of the thyroid gland.

The internal jugular vein follows its normal course.

The arteries of the left side of the neck show no special peculiarities.

THREE CASES OF MALFORMATION OF THE TRACHEO-ŒSOPHAGEAL SEPTUM.¹ By ARTHUR KEITH, M.D., and J. E. SPICER, M.B.

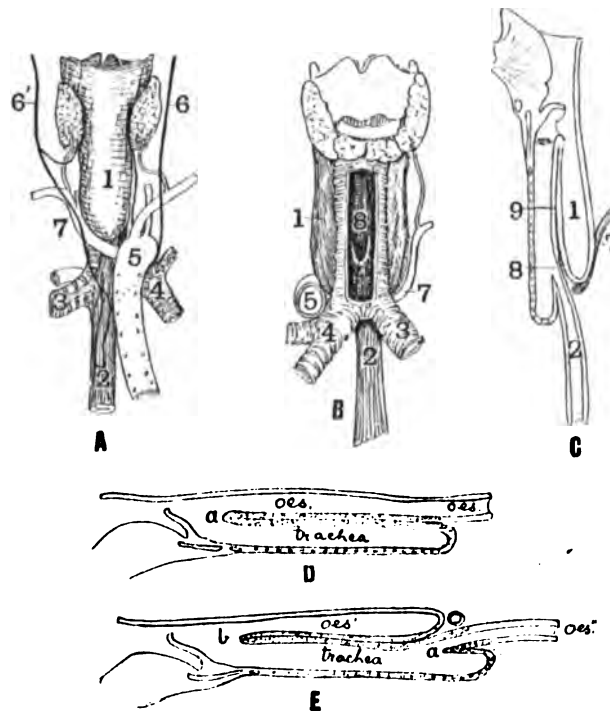
SIR MORELL MACKENZIE, in his *Manual of Diseases of the Throat and Nose* (vol. ii. p. 216, 1884), gives a summary of sixty-three cases of malformation of the œsophagus of which only one had been seen by himself, and mentions as a remarkable fact that Hirschsprung had four cases brought to him in a period of six months. The three specimens which are described here came into our possession since July of last year, two in the London Hospital, in cases which were under the care of Dr Percy Kidd, and one of which occurred in the practice of Dr G. H. Harvey of Peckham. But we do not record these cases here because of their rarity, but because, in the first place, the nature of these malformations is not generally understood by those who describe them in the medical press; secondly, because in all three cases there was present a right aortic arch or its representative—namely, a right subclavian artery arising as the last trunk from the aortic arch; and thirdly, because such records as are to be found in literature are usually not accompanied by illustrations which fully explain the condition. Reference to the valuable "Reports on Recent Teratological Literature" published in this Journal by Professor Windle, justifies us in believing that the nature of these œsophageal malformations has not received much attention in late years. A convenient summary of the present state of our knowledge regarding malformation of the œsophagus will be found in Dr J. W. Ballantyne's *Antenatal Pathology*, vol. ii. p. 462, 1904.

CASE A (see fig. A).—A male, full-time child, who lived a few hours. The œsophagus, at the junction of the upper two thirds and lower third of the trachea, terminated in a dilated *cul-de-sac*. The lower part of the œsophagus opened from the dorsal aspect of the bifurcation of the trachea, so that its musculature was continuous with that of the trachea and bronchi. There was a right aortic arch (fig. A); the left subclavian arising last from the arch of the aorta and passing behind the trachea, just below the *cul-de-sac* of the œsophagus, thus reached the left arm. The left inferior laryngeal nerve passed straight to the larynx. Hare-lip and cleft

¹ Read before the Anatomical Society of Great Britain and Ireland, March 1906.

palate were present. There was a wide interventricular foramen due to non-fusion of the endocardial cushions. Family history not obtained.

CASE B (fig. B).—A boy, lived six days. No other malformation was observed at the post-mortem examination. A right aortic arch was present with the left subclavian, arising as in case A. The upper segment of the oesophagus formed a widely dilated diverticulum, and reached to the bifurcation of the trachea. The lower segment of the oesophagus opened in the posterior wall of the trachea at the junction of the middle and lower thirds



of that channel. Its orifice was bounded below (see fig. B) by a crescentic fold, the lateral margins of which turned upwards over the free ends of the tracheal rings. The *cul-de-sac* of the upper segment of the oesophagus overlapped the origin of the lower segment, to which it was joined by a strand of muscular tissue. Only meconium was passed per anum. Milk was vomited at once, and was blood-stained. The family history showed that the parents and their other six children were normally developed.

CASE C (see fig. C).—A well-developed child, female, lived nine days. The condition was similar to case B, with the exception that the arch of the

aorta crossed the left bronchus and gave off the right subclavian artery as its last branch. As in the last case, the subclavian artery lay in the cleft between the upper and lower segments of the œsophagus. Two supernumerary auricles occurred near the right ear. Hair on scalp long and black. Bullæ on upper part of trunk. Congenital syphilis(?) Vomited immediately on taking food. Vomit blood-stained. Passed meconium and urine. Parents and their three children normally formed. We are indebted to Dr Percy Kidd for permission to examine and report on cases B and C.

The normal formation of the tracheo-œsophageal septum is clearly shown in the embryological models and publications of His. At the end of the third week (embryo 3.2 mm.) the floor of anterior part of the primitive œsophagus is depressed or evaginated, so that in this segment of the foregut one may recognise a dorsal or œsophageal and a ventral or tracheal division which are separated by lateral ridges which meet behind in a crescentic fold. From the posterior or caudal end of the tracheal division, under the crescentic fold, arise the lung buds. By the end of the fifth week (embryo 12.5 mm. long) the crescentic fold has spread forwards, uniting the lateral ridges, so that the tracheal and œsophageal divisions of the foregut become completely separated from each other by the formation of the tracheo-œsophageal septum. The interarytenoid fold represents the anterior end of the septum (see fig. D).

To produce the malformations described here, the tracheo-œsophageal septum is evidently formed in the manner shown in fig. E; the lateral tracheo-œsophageal ridges and fold, instead of proceeding horizontally backwards so as to meet between the lung buds and œsophagus, and so divide the primitive œsophagus into a dorsal and ventral division, proceed obliquely backwards and dorsalwards so as to meet on the dorsal wall of the foregut (see fig. E). In case A, where the œsophagus continues backwards in the line of the trachea, this apparently has been the case, but in the commoner forms shown in B and C (see figs.) it is evident that the tracheo-œsophageal septum must have been formed in two parts. The partition between the lower segment of the œsophagus and trachea (see fig. E, *a*) represents the posterior part of the normal septum, while *b* represents the anterior part of the septum formed by the obliquely situated tracheo-œsophageal ridges. Morell Mackenzie cites three cases in which the lower segment of the œsophagus opened from a bronchus, from which fact we conclude that the trachea and bronchi (right and left) are derived directly from the foregut by a subdivision of that channel into a dorsal and ventral division by the formation of the tracheo-œsophageal septum, and that only the lungs and intrapulmonary bronchi are formed by a process of out-budding.

The fistulæ which are occasionally found between the oesophagus and trachea are apparently due to a partial failure in the union of the lateral ridges which normally unite to form the tracheo-oesophageal septum.

Since recording the above cases we have had an opportunity of examining a fourth. In this case there was no representative of a right aortic arch; there was atresia ani and malformation of heart.

EXPLANATION OF FIGURE.

- A. The oesophagus, pharynx, trachea, and arch of the aorta of case A seen from behind.
- B. The same parts of case B, seen from the front, with the trachea opened to show the oesophageal orifice.
- C. The same parts in case C, shown in section from the side.
- D. Diagram to explain the normal position and relationships of the tracheo-oesophageal septum. The septum is stippled.
- E. Diagram to explain the abnormal position of the tracheo-oesophageal septum.

- (1) Upper segment of oesophagus ending in a *cul-de-sac*.
- (2) Lower segment of oesophagus.
- (3) Left bronchus.
- (4) Right bronchus.
- (5) Arch of aorta.
- (6, 6") Left and right vagus nerves.
- (7) Subclavian artery.
- (8) Tracheal orifice of lower segment of oesophagus.
- (9) Tracheo-oesophageal septum.

TWO CASES OF FUSION OF THE SEMILUNAR AND CUNEIFORM BONES IN NEGROES. By DOUGLAS E. DERRY, M.B.,
Ch.B., *Assistant Professor of Anatomy, Egyptian Government School of Medicine, Cairo.*

At a meeting of the Anatomical Society held in February 1893, the Proceedings of which are published in the *Journal of Anatomy*, vol. xxvii. p. xxii, Professor A. M. Paterson showed, amongst other anomalies in a negro skeleton, a fusion of the semilunar and cuneiform bones in the carpus of the *right hand*; and he mentioned that Humphry (*The Human Skeleton*, p. 397) also records a similar case in a negro skeleton in the Museum of the Jardin des Plantes (Jourdan, *Encycl. Anat.*, II. 139). Whether or not this is the same case that Testut (*Traité d'Anatomie humaine*, 4^e édit., tome 1, 1889, p. 283) mentions as having been described by Soemmerring—"Soemmerring a vu, sur les deux mains d'un nègre, les os du carpe réduits à sept, par suite de la soudure du semilunaire avec le pyramidal"—the writer is unable to say, as Soemmerring's work is not available for reference in Cairo.¹

In 1903 Professor Elliot Smith published in the *Anat. Anzeiger*, Band xxiii. p. 494, a case of numerical reduction of the carpus in a male Sudanese negro. In this instance the semilunar and cuneiform bones were completely fused on both sides, and there was no evidence whatever of inflammatory action. At the time, he was able to find only one record of such an anomaly—Testut's reference to the case of the negro described by Soemmerring. After the publication of his note, Professor Paterson called his attention to the case that he had recorded (*op. cit.*, *supra*).

Since then Professor Elliot Smith has made a systematic examination of the carpus in the skeletons of over 500 predynastic Egyptians, as well as in a much more numerous series of bodies of later Egyptians of every period, without meeting a single case of fusion of any of the carpal bones.

During the past winter, forty bodies have been examined in the dissecting-room of the Cairo School of Medicine, six of which were

¹ Dr R. J. Anderson described in this *Journal*, vol. xvii. p. 255, 1883, coalescence of the semilunar and cuneiform bones, and referred to a similar specimen described by Wagner in *Heusinger's Zeitschrift*, vol. iii.—Eds.

Sudanese negroes. Two cases of fusion of the carpal bones have been seen. Both of these were in Sudanese subjects, one a male and the other a female. The latter showed the condition in both wrists, but unfortunately, in the case of the male subject, the right hand was destroyed before it could be examined. The fusion was well seen, however, in the left joint.

In these three hands there was a complete union of the semilunar and cuneiform, and on making a transverse vertical section through the proximal row of carpal bones, it was found that the cancellous tissue was absolutely continuous between the bones.



FIG. 1.—The bones of the *left* carpus of a Sudanese negress. The proximal row has been sawn through, and the parts opened out. The hand is in the prone position.
 FIG. 2. The *right* carpus of the same subject as in fig. 1, showing the superior surface of the proximal row (pronated).
 FIG. 3.—The *left* carpus of a Sudanese negro, treated in the same way and in same position as fig. 1.

The accompanying photographs show the condition very distinctly.

Fig. 1 is the left hand of the female subject, in which the proximal row of carpal bones has been sawn through and the parts opened out. The hand is in the prone position, as is also the case in the other figures. Fig. 2 shows the right hand of the same subject. In this figure, which is a view of the superior surface of the proximal row, it will be noticed that the surface of the combined os lunato-triquetrum is perfectly smooth, and that there is no indication of any division between the bones. On the inferior surface, however, as is shown in figs. 1 and 3, there is in both cases a slight but distinct depression in the cartilage at the site of the normal articular surfaces, and a spur of this tissue projects

58 Fusion of the Semilunar and Cuneiform Bones in Negroes

into the cancellated bone for about 2 mm. Fig. 3 is the left hand of the male subject. In figs. 1 and 3 this small spur of cartilage is best seen with the aid of a lens.

If the case described by Soemmerring is different from that mentioned by Humphry, the total number of recorded cases, including the two in the present communication, amounts to six. It is remarkable that all these occurred in negroes, one being recorded in Great Britain, two on the Continent, and three in Cairo.

With the kind assistance of Mr Owen Richards, resident surgeon to the Kasr el Ainy Hospital here, the writer examined the wrists of all the negroes at present in the wards, by means of the Röntgen rays, but found no case of fusion of the bones.

EPILUNAR AND HYPOLUNAR OSSICLES, DIVISION OF THE
SCAPHOID, AND OTHER ABNORMALITIES IN THE CAR-
PAL REGION. (Illustrated by drawings from two specimens.)
By HENRY M. JOHNSTON, M.B., *Chief Demonstrator of Anatomy,*
Trinity College, Dublin.

IN addition to the proximal row of three cartilaginous elements (excluding the pisiform), and the distal row of four, in the development of the human carpus a number of accessory cartilages appear at an early stage, which later are either absorbed altogether, or unite with neighbouring cartilages forming projections upon them; or in rarer cases remain separate, and, after ossification, form distinct elements. Their significance is very obscure. One of them, the os centrale, when present, evidently corresponds to the bone so named in lower forms; but little is known of the other varieties of accessory ossicles.

In recent years it has been shown, by the study of skiagraphs of the wrist, that these supernumerary carpal bones, especially the os centrale, are by no means so rare as they were formerly supposed to be, and in the living subject they have been frequently demonstrated. Notwithstanding, it is extremely difficult to obtain specimens in the dissecting room. This is due to the fact that the student is liable to remove them when cleaning off the ligaments; and after maceration if an extra bone is found, it is difficult or impossible to determine its position and relations. Consequently, few instances are recorded in English anatomical literature; and the only reference to the subject in the *Journal of Anatomy and Physiology* is the review on Gruber's investigations on the os centrale, vol. xviii. p. 119, and Sir William Turner's paper, vol. xvii. p. 244.

The two specimens which are described in this paper are examples of these extra ossicles; but in addition, one of them presents other abnormalities which are extremely interesting, whether they be considered congenital or pathological.

An investigation upon the frequency of occurrence of different varieties of supernumerary ossicles and other congenital abnormalities in the carpal region, was made by the late Professor W. Pfitzner of Strasburg, and published in *Zeitschrift für Morphologie*, 1900, p. 77. His paper is very

exhaustive, and the value of his research is much enhanced by his having himself dissected and prepared the specimens he describes.

Last winter, while dissecting the dorsal surface of a wrist-joint from a male subject, I noticed that an abnormal bone was present. The other hand of the subject was secured, and was also found abnormal. Both specimens were exhibited to the Anatomical Society of Great Britain and Ireland at their meeting last March.

SPECIMEN 1—Right hand, dorsal aspect (fig. 1).—The bones of the first



FIG. 1.

row are exhibited in the figure somewhat separated from each other, and a very superficial inspection is sufficient to show that the lunar and scaphoid are abnormal. The lunar bone, at its radial distal angle, is markedly elongated and prominent, and curves towards the radial side. This prominence, consisting mainly of a separate bone, is oval in shape, with its long axis placed transversely to the long axis of the forearm, and it is joined to the lunar by fibrous tissue; at the same time it is freely movable. Its anterior aspect is coated with cartilage, part of which articulates with a flattened—almost circular—facet, coated also with cartilage on the dorsal surface of the scaphoid at its ulnar extremity. It was united to the

scaphoid by a capsular ligament, and the synovial cavity of the joint thus formed was continuous with that of the mid-carpal articulation. The ulnar part of its anterior articular surface, in palmar flexion, articulates with the head of the os magnum; but in extension and dorsiflexion this facet is free, and overhangs the neck of the os magnum. The posterior surface of the ossicle is convex and free: its edges are thinner than the centre; and its length from side to side is 1.3 cm., whilst its breadth is 9 mm.

The flattened, almost circular, facet on the scaphoid is situated at the ulnar extremity of the dorsal surface, between the articular surfaces for the trapezoid and radius.



FIG. 2.

In fig. 2, the lower two bones are the scaphoid and lunar of this specimen. The lunar, on the left side, shows the radial and dorsal surfaces and the accessory bone attached; and the scaphoid, on the right side, shows the circular facet with which the ossicle articulates.

This bone corresponds in position to what Gruber described as the rarer form of os centrale; but, according to Pfizner, there are not two varieties of os centrale, and it answers to his description of the Epilunar, which he defines as a cartilaginous nodule appearing at an early age, generally becoming fused with the radial distal corner of the lunar, but sometimes remaining separate and becoming ossified in that position.

It may be asked—Can we normally detect any evidence of the presence

of this Epilunar? If the upper two bones in fig. 2 be examined, it will be evident that this rudiment does not disappear without leaving some trace behind. The bones in the figure were taken from ordinary class specimens. The left one shows a lunar bone, drawn in much the same position as the abnormal specimen just below it. It will be noticed that its dorsal surface is elongated radially into a spur, and this projection is formed by the fusion of the Epilunar cartilage. The projection may not be always so prominent



FIG. 3.

as in this case, but still every lunar will show it to some extent on the dorsal surface at the radial side. In the same figure the right of the upper two bones shows a normal scaphoid; its dorsal non-articular surface exhibits a depression or notch at its ulnar extremity. This notch is almost constant, and represents the position which the Epilunar once occupied. It will be seen to correspond to the circular facet on the bone figured below.

SPECIMEN 1—Palmar aspect (fig. 3).—The lunar bone in this figure seems to have had its radial distal end cut off. This separate portion is a distinct ossicle; its ligamentous connection with the scaphoid has been

retained with the object of preserving its position. It has been dragged apart from the lunar so that its shape may be seen. Quite close to it is another very minute nodule of bone in the ligament uniting it with the scaphoid.

The bone itself is .9 cm. in its longest diameter, .5 cm. from before backwards, and .2 cm. in thickness. Its distal and palmar surfaces are non-articular. It articulates with the head of the os magnum by a narrow linear facet, which is continuous with the concave facet on the lunar for



FIG. 4.

the os magnum; this surface as well as that co-apted with the lunar is coated with articular cartilage.

This bone corresponds to what Pfitzner has named the Hypolunar; it lies at the palmar distal radial angle of the lunar. The Hypolunar, which may exist as a separate nodule of cartilage at an early age, usually fuses with the lunar, but an indication of its presence in a normal bone may be found in the marked projection of the palmar distal end towards the radial side.

There is no other abnormality in this carpus.

SPECIMEN 2—*Left hand, dorsal aspect* (fig. 4).—The left hand, when examined dorsally, presents a most peculiar appearance. Every bone is very much larger than on the right side, and the enlargement extends to radius and ulna. The bones of the second row do not present any abnormality except at the junction of the third metacarpal and os magnum. Here the styloid process of the former, together with a portion of the radial distal end of the os magnum, projects backwards for a distance of 7 mm. The articulation between the two bones is linear, and so intimately united were they (by ligament), that it seemed at first as if they were completely fused together. One other instance of this condition has been recorded in the *Journal of Anatomy and Physiology*, vol. xxviii., in the Fourth Annual Report of the Committee of Investigation of the Anatomical Society for the year 1892–1893.

The first row of bones is very abnormal. The scaphoid is seen to be divided into two completely separate portions—a proximal and a distal—the division being oblique from side to side.

The proximal portion, which seems degenerated and incompletely divided into several pieces, is joined by the superior scapho-lunar ligament to the lunar, and includes the ulnar part of the radial articular surface as well as a small part of the articular surface for the os magnum. To the distal portion belong the facets for the trapezium and trapezoid, which are normal, the whole of the posterior surface (which is very prominent and of greater breadth than usual), and the greater part of the concavity for the head of the os magnum.

Attached to the lunar by fibrous tissue, and situated between the scaphoid, lunar, pyramidal, and os magnum, a separate and distinct bone is found. It is larger than that found on the dorsum of specimen 1, but corresponds to it in position. It was united by ligament to both parts of the scaphoid, but from the distal portion it has been separated in the figure. Its dorsal non-articular surface continues the prominent dorsal surface of the scaphoid ulnar-wards, and almost meets the posterior surface of the pyramidal. Its anterior surface is concave, and articulates with the head of the os magnum; it is connected by ligament to the radial distal end of the lunar.

The bone is of somewhat quadrilateral shape: its longest diameter, 1.5 cm., is placed transversely; it is 1.1 cm. from above downwards at its widest part, and of about .4–.5 cm. in thickness.

This Epilunar differs mainly from that on the right side in having a more extensive articulation with the os magnum, in being larger and of different shape.

On the palmar surface, except the fissure caused by the division of the scaphoid, nothing abnormal is to be noticed. The line of division starts from the level of the styloid process of the radius, and runs ulnar-wards and slightly distally. The tubercle of the scaphoid is included in the distal portion.

It might be said that these extra bones were the result of rheumatic arthritis, and are merely deposits of pathological material. The age of the subject was stated to be seventy years, and might be taken as supporting this view. Yet in other ways the subject did not present appearances corresponding to so great an age, and indeed it is quite probable that the individual was not more than fifty years. All the other joints were carefully examined, and the articular surfaces were found smooth. The bodies of the lower cervical-vertebræ were ankylosed together, but beyond this there was no evidence of rheumatism. The symmetry of the Epilunar, and the precise position of it and of the Hypolunar, are in favour of the view that they are of congenital origin. Dr W. S. Haughton very kindly took some stereoscopic X-ray photographs of the specimens, and the prints show in a most striking and beautiful manner the cancellous tissue within the abnormal ossicles. They must be regarded, therefore, as composed of true bone. How is one to account for the peculiar appearance in the left hand of the bones of the first row? I think the examination of the shoulder of that side supplies the answer. There was found a perfect example of fracture of the coracoid process of the scapula; about half an inch of the process was completely separate. Into this separate portion the coraco-acromial ligament, and part of the tendon of the pectoralis minor muscle, were inserted, and from its extremity almost all of the short head of the biceps and coraco-brachialis arose. It seems likely, therefore, that the subject when living had at some previous time received a severe fall on the hand, and that the division of the scaphoid is to be regarded as an ununited fracture; and further, that the thickening of the lower end of the radius is due to trauma. The opposing surfaces of the scaphoid are not coated with cartilage, and X-ray examination has shown that fracture of the scaphoid is by no means of such a rare occurrence.

It should, however, be noted that the condition of the scaphoid almost exactly corresponds to the congenital division such as Pfitzner describes, even the upper part being broken up and degenerated. Why the bones of the left hand should be so very much larger than those of the right, I have been unable to discover. The presence of so many abnormalities in a single pair of wrists is certainly remarkable.

THE DEVELOPMENT AND EVOLUTION OF THE "PAPILLARY"
RIDGES AND PATTERNS ON THE VOLAR SURFACE OF
THE HAND.¹ By EVELYN JOHN EVATT, *Assistant in Anatomy,*
University College, Cardiff.

THE following account is based on observations made almost exclusively on the human hand. The dates given are rough approximations; they were inferred by comparing the fetuses from which the specimens were taken with the figures found in the section on "General Embryology" in the *Text-Book of Anatomy*, edited by Cunningham. The volar surface of the developing human hand presents a number of well-defined pads; they are first recognisable about the sixth week of intrauterine life, and have attained their maximum relative development by the fifteenth week; after this period they are to be regarded as decrescent. The morphology of these pads has been worked out by Johnson, Klaatsch, Inez L. Whipple, and Wilder with a thoroughness that would seem to leave nothing to be desired. In the adult the sites of the pads are occupied by papillary (epidermic, Inez L. Whipple) ridge patterns. The design formed by these ridges on the volar surface of a terminal phalanx may be regarded as the most typical expression of a pattern, and the term "pattern" in the text will be used to describe such formations. For a full and detailed description of the outlines and cores of finger-tip patterns, Galton's *Finger Prints* may be consulted.

The method employed in the preparation of the specimens, from a study of which the results stated in this paper were arrived at, was briefly as follows: the skin was removed from the volar surface of the terminal phalanx of the thumb, stained, dehydrated, and cleared in clove oil; camera-lucida drawings were made of the surface views of the pieces under the microscope, the pieces were then embedded in paraffin, and a number of vertical sections were taken from each; these were mounted and photographed.

An undifferentiated area of nucleated cells is all that can be seen in a surface view of the skin at seven and a half weeks: a vertical section from this piece (fig. 1) shows that the deepest layer of the

¹ Read at the Anatomical Society of Great Britain and Ireland, March 1906.

epidermis consists of columnar cells. The epidermis lies flat upon the corium, from which it is demarcated by what appears to be a well-defined basement membrane. The epidermis in a number of these sections was widely separated from the corium, indicating that these two surfaces were but loosely attached to each other. The surface is quite smooth.

Surface views of layers of skin, at eleven weeks, present a striped appearance, dark and light lines alternating, and designs technically known

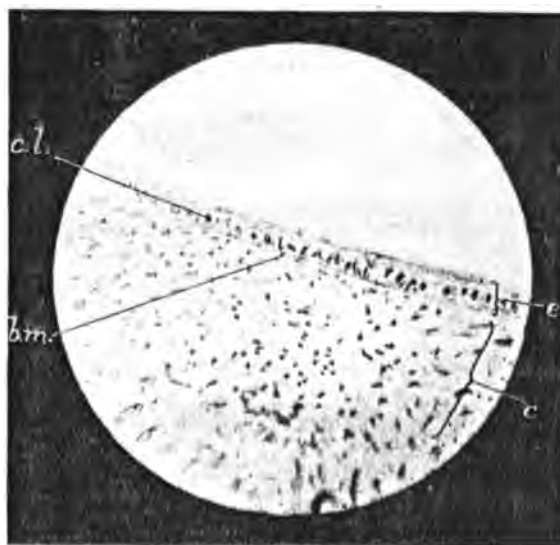


FIG. 1.—Vertical section of skin, fetus aged seven and a half weeks.
e, epidermis; *c*, corium; *c.l.*, layer of columnar cells; *b.m.*, "basement membrane."

as patterns are to be seen. Fig. 2 is a vertical section from one such piece. It shows the epidermis as having invaded the underlying corium in a wavy outline; the layer of columnar cells is well marked and follows the undulations of the epidermis; the remaining cells of the epidermis are polyhedral in shape and all traces of a basement membrane have disappeared; the surface is quite smooth, there are no "epidermic" ridges. It may be as well to state here that the term "subdermal" ridges in the text will be held to apply to the wedge-shaped epidermal invasions (fig. 2). Inez L. Whipple has happily suggested the term "epidermic" ridges for the minute ribs which cover the volar surface of the hand, and of which an impress may be taken.

Although, from about the tenth week onwards, surface views of cleared pieces of skin from the volar surface of the terminal phalanges of the finger-tip pads present distinct typical patterns, and later the positions of the rudimentary sweat glands, it is not until about the eighteenth week that the cells on the bases or free surfaces of the subdermal ridges are found to have proliferated and to lie in ribs upon the surface (figs. 2 and 3); the ribs are the rudiments of the epidermic ridges. Sections at this age (fig. 3) show the summits of the papillæ of the corium lying at the bottom of the

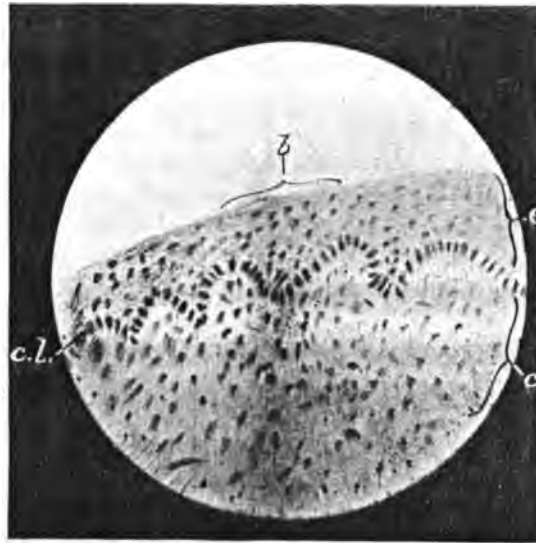


FIG. 2.—Vertical section of skin, *fœtus*, aged eleven weeks, shows four "subdermal" ridges. *e*, epidermis; *c*, corium; *c.l.*, layer of columnar cells; *b*, base of a subdermal ridge.

troughs formed between collateral epidermic ridges, while from the apices of the subdermal ridges sweat glands are seen to be passing into the corium. Traces of the sweat glands are found long before the epidermic ridges have appeared. An examination of the skin from the finger-tips of numerous fetal hands in which the subdermal ridges had appeared, revealed the presence of a variety of patterns, such as one might expect to find on the finger-tips of an adult hand, although the patterns were not present on the surface.

A study of the accompanying figures and of the text will have shown that the following facts are demonstrable.

Patterns are found only on the sites originally occupied by the pads,

elsewhere on the palm the ridges are disposed transversely or obliquely to the long axis of the limb.

Patterns are present below the surface before their counterparts (epidermic ridge patterns) appear on the surface of the skin.

In ontogeny the patterns are primordial, that is to say, the relative positions of the ridges forming a pattern are primitive conditions.

The following statement of a theory of the evolution of the epidermic ridge patterns in phylogeny is suggested.

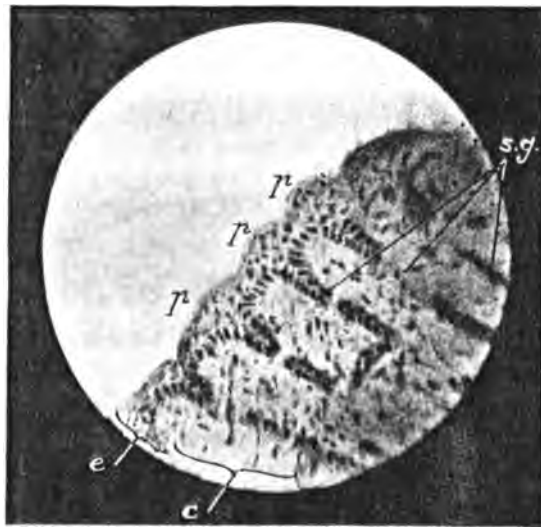


FIG. 3.—Vertical section of skin, fetus aged eighteen weeks. *e*, epidermis; *c*, corium; *s.g.*, sweat glands; *p*, papillary or epidermic ridges.

The epidermis originally invaded the corium in parallel ridges. This corrugating invasion tended, no doubt, to strengthen the attachment between the two structures.

The ridges were at first disposed transversely to the long axis of the limb, both over the pads and the rest of the palm, a disposition which may be observed on the adult hand at the bases of the patterns. Hepburn and Klautsch have drawn attention to this transverse disposition of the ridges on the ventral surface of the prehensile tail of the nigger monkey; the transverse arrangement is particularly well marked on the terminal segment.

When the hand assumed the function of grasping in the early history

of man, the pads tended to follow the stresses of prehension; therefore the finger-tip pads, with their associated subdermal ridges, assumed a distal inclination, and the ridges were thrown into arches with their convexities directed distally. The remaining pads, with their respective ridges in obedience to the stresses of prehension, inclined proximally, and these particular ridges formed arches whose convexities were directed towards the base of the hand.

At first the inclining of the pads by the stresses of prehension would throw the ridges into a series of plain arches, it therefore appears that the "plain arch" is the most rudimentary of the patterns; later the more complex patterns were evolved as a result of the inclining of the pads with their associated subdermal ridges in the varying directions of the stresses of prehension.

A "plain arch" pattern may be experimentally produced by laying lengths of cord in parallel rows across a cone of some plastic material, *e.g.* modelling clay, and then shoving or dragging over the summit of the cone. The pieces of cord representing ridges will now be seen to be drawn into arches, the degree of arching being proportional to the amount of the stress of prehension, and the plain-arch pattern is produced.

The different phases in the transition of a transverse ridge to an arch, loop, or whorl may be traced on their respective finger-tip patterns. In any one of these patterns, the ridges at the proximal end of the pattern, where the inclining of the pad was least, are disposed transversely, whereas at the centre, where the inclining was greatest, the ridges are thrown into forms characteristic of core centres; and finally, from the centre to the distal end, where the inclining was intermediate in amount, the ridges are seen to be in arches successively more open. The subdermal ridges (fig. 2) did not yield under pressure to the same extent as the intervening shallower portions of the epidermis, they were consequently more exposed to pressure, and as this caused them to hypertrophy, they came to be elevated in ribs above the level of the surface (fig. 3); these ribs constituted epidermic ridges, and as they were moulded on the subdermal ridges, they produced a faithful replica of them and delineated the underlying pattern.

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THE ANATOMICAL VARIATIONS PRESENTED BY A CASE OF A
THORACOPAGOUS LAMB MONSTER, TOGETHER WITH AN
ACCOUNT OF THE DEVELOPMENTAL EXPLANATION OF
THE SAME. By RICHARD J. A. BERRY, M.D. Edin., M.D. Melb.,
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the Royal Colleges, Edinburgh.*

SOME few years ago Professor Berry was fortunate enough to have presented to him by Dr F. W. N. Haultain of Edinburgh, two cases of human thoracopagous monsters, which were carefully dissected and fully described in the *British Journal of Obstetrics and Gynecology* and elsewhere (1). More recently Professor Berry was similarly fortunate in having presented to him by Dr A. J. Beattie the same monstrosity occurring in a lamb. The dissection of this last case was undertaken by Dr J. D. Sinclair.

The present example is a double female thoracopagous lamb monster of the sub-type known as sternopagus tetrabrachius, that is to say, each twin has two upper limbs, and the internal organs, more particularly the heart, show various degrees of fusion. The present specimen came from a large sheep-farm at Luib, in Perthshire, Scotland, and if the shepherd may be believed, its rarity is shown by his statement, that it is the first example of the kind which he has met with in an experience of forty years with an average of 1000 lambs per annum.

External Appearances.—The line of fusion extends from the upper part of the thorax opposite the fore-limbs to the umbilicus. Both upper and lower limbs are perfectly free, and are consequently eight in number. The twin on the right—hereafter always referred to as the right twin—measures, on the dorsal surface, from the tip of the nose to the tip of the tail, 40 cm., whilst the left twin similarly measures 46 cm. The umbilicus is single and common to both twins, and contains three vessels. Coils of jejunum-ileum are distinctly visible at the umbilicus, shining through the peritoneum. Along the thoracic line of junction is to be felt a distinct bony ridge.

The abdominal viscera were first dissected out and thereafter the thoracic

viscera (fig. 1). As the various stages of the dissection were identical with those of the human cases already referred to (1), it is unnecessary to describe them again.

The Alimentary System.—Each twin possesses a stomach fully formed and developed and composed of four parts—a rumen, a reticulum, a

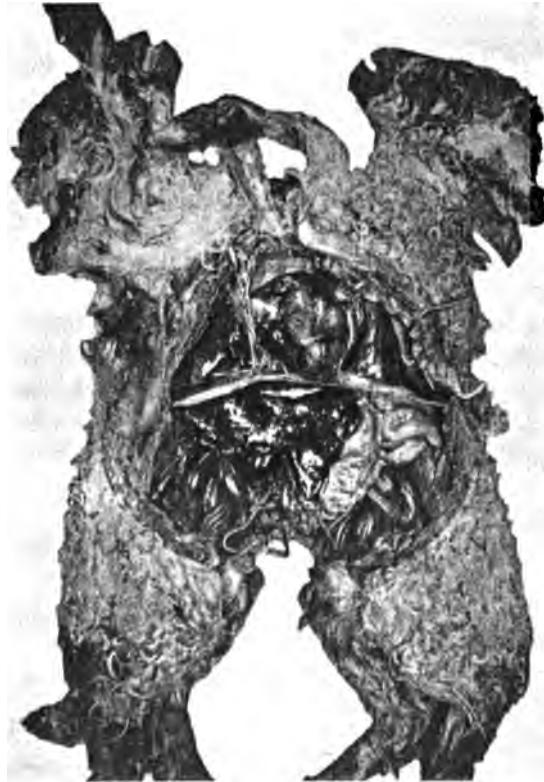


FIG. 1.—A stage in the dissection showing the mesially situated and common heart, the liver, gall-bladder, etc.

psalterium, and an abomasum. From the abomasum proceeds a duodenum which unites with the duodenum of the opposite twin, so that there is a single duodenal tube common to both twins. The duodenal tube measures in all 20 cm.—11 cm. of which belongs to the right twin, and 9 cm. to the left twin. From the junction of these two duodenal tubes proceeds a single jejunum common to both twins, and which measures 162 cm. The jejunum possesses a mesentery on both sides, with blood-vessels running along both

borders, and terminates below in a slight, pouch-like dilatation 3 cm. in diameter. From this point onwards each twin possesses its own independent alimentary canal. Arising from the pouch-like dilatation in which the common jejunum ends are the two ilea, one for each twin, each of which measures 67 cm. Each ileum terminates at its own ileo-cæcal junction, the position of which is marked by a large lymph gland. The large intestine is perfectly normal in each twin and measures 74 cm. in length, whilst the cæcal portion is 6 cm. in length. The alimentary canal is therefore perfectly normal, with the exceptions of the fused duodena and of the single jejunum common to both twins, that is to say, the alimentary abnormalities are exactly as they were in the two human instances previously referred to (1).

The liver is a single structure common to both twins, which sits, as it were, astride of the common and single duodenal tube. That it really results from the fusion of two separate livers seems almost certain, because two gall-bladders are present, and there are two distinct series of biliary ducts.

The pancreas is reduplicated, there being one for each twin. Each pancreas is normal in position and is applied to the stomach and duodenal tube. The common bile-duct and the duct of Wirsung join together to form a single duct, and the single ducts so formed—one in each twin—unite together and open by a common orifice into the duodenal tube exactly opposite the commencement of the jejunum.

The Respiratory System.—The respiratory system is perfectly normal. Each twin possesses two pleural membranes and two lungs.

The Vascular System.—The vascular system, as might be expected from the thoracic fusion, is extremely abnormal. There is a single pericardial cavity, mesially situated, containing a single heart common to both twins.

The heart is, as stated, a single structure common to both twins. It lies mesially, in the pericardial sac. What appears externally to be a large left ventricle occupies the major part of the anterior surface and forms the true cardiac apex. This ventricle is separated from what appears to be a right ventricle by an interventricular groove. At the basal portions of these apparent ventricles, and overlapping them, is what appears to be a single auricle, but there are, nevertheless, four distinct auricular appendages.

On opening up the heart it was at once obvious that the apparent single heart was, in reality, two hearts fused into one. In this instance there are four auricles and four auricular appendages, and four ventricles. The heart primarily belonging to the left twin is the more nearly normal of the two.

A reference to fig. 1 will show that the only abnormalities in the heart of the left twin are :—

1. Incomplete separation of the two ventricles.
2. Failure of the inferior vena cava to open into the right auricle.

An examination of the same figure will show that, as regards the heart of the right twin, the abnormalities are more numerous, thus :—

1. The right side of the heart is inverted.
2. The separation of the two ventricles is even more incomplete than in the left twin.
3. The mitral and tricuspid orifices are fused into one.
4. The superior vena cava is absent.
5. The inferior venæ cavæ fuse into a single vessel which opens into the right auricle of the right twin.

The most remarkable variation in the great vessels of the left twin is the fact that the aorta and pulmonary artery, after an independent course from their respective ventricles, unite together beyond the origin of the right common carotid to form a single vessel, which is then continued onwards as the thoracic and abdominal aortæ. From the thoracic portion of this fused vessel arise the right and left pulmonary arteries.

From the arch of the aorta prior to its fusion with the pulmonary artery, arises, first, an innominate artery which divides into the left subclavian and left common carotid arteries, and second, the right common carotid artery.

The pulmonary artery, prior to its fusion with the aorta, gives off no branches whatsoever.

Beyond the fusion of the two main vessels arise the right subclavian artery, the right and left pulmonary arteries, and subsequently the two hypogastric and external iliac arteries.

The most remarkable variations in the great vessels of the left twin are therefore :—

1. The junction of the aorta with the pulmonary artery.
2. The abnormal origins of the right and left pulmonary arteries.
3. The abnormal origins of the two hypogastric arteries.

In the right twin, as in the left, the aorta and pulmonary artery again join beyond the origin of the left common carotid to form a single vessel. Prior to its junction with the pulmonary trunk the aorta first gives off an innominate artery which divides into a right subclavian and a right common carotid artery, then comes the origin of the left common carotid, after which the aorta is joined by the pulmonary trunk.

From the conjoined trunk arise the right and left pulmonary arteries, and thereafter the left subclavian. From the abdominal aorta arises a single hypogastric artery.

The most remarkable variations in the great vessels of the right twin are therefore:—

1. The junction of the aorta and pulmonary artery.
2. The abnormal origins of the right and left pulmonary arteries.
3. The presence of but one hypogastric artery.

The superior venæ cavæ are represented by a single trunk developed mainly in connection with the left twin, and joined by a smaller vessel from the right twin. The single trunk so formed opens into the right auricle of the heart of the left twin.

The inferior venæ cavæ are two in number—one from each twin. They ascend from their respective abdominal cavities through the liver, in which they fuse together to form a single trunk which opens into the inverted right auricle of the right twin. Such being the more remarkable of the variations found in this specimen, it is now necessary to say something as to their embryological explanation.

Origin of Double Terata.—Amongst the numerous theories which have been put forward to account for the origin of double terata, one of the earliest was that which regarded them as due to the fusion of two originally separate ova. This theory is not, however, supported by fact, and is untenable.

A second theory of diplogensis supposes the splitting or fissuring of an originally single embryo, but here again neither experimental teratology nor observed facts support such a view.

Neither of these theories being sufficient to explain the numerous phenomena recorded, "it is now reasonable," according to Ballantyne (2), "to suppose that the double nature of the organism is determined before the appearances of the rudiments of the embryo in the germinal area . . . and that the formation of double monsters is decided either before or during impregnation, and not after the appearance of the embryo. It is due therefore to a germinal cause."

Working on this hypothesis, Berry first endeavoured to explain his two cases of human thoracopagi (1) by assuming the formation of two primitive grooves on a single ovum produced by bilateral segmentation. The position was, however, untenable, and was abandoned in favour of the supposition that "the two embryos had been developed from a single ovum without bilateral segmentation." This latter theory was found to account for the various abnormalities then recorded, and it is perhaps not unreasonable to assume that this may eventually be found the correct theory of the development of thoracopagous monsters.

In favour of this theory there are the following facts:—

1. Numerous instances have been recorded of duplicity upon a single

ovum. References to two such cases will suffice. Bryce (3) has described a case of anterior duplicity in a chick embryo of thirty-four hours, in which there were two separate notochords throughout. The medullary canals were in part separate and in part fused.

Miss Duncan of Aberdeen (4) has described a similar case of posterior duplicity in a chick embryo, under the title of the "Anatomy of a Double Chick Embryo."

2. Laguesse and Bue (5), in an account of a monster with two heads and one body measuring only 19 mm. in length, state that they think that there were first two primitive lines close to one another, and slightly curved, with their convexities directed towards one another. At the extremities of these two lines were developed two distinct cephalic prolongations, two neural canals, and two notochords. Up to this point it would have been possible to have had a pair of twins from this condition had the two primitive lines been sufficiently distant from one another. But so close were they that there was between them posteriorly only a narrow territory of common blastoderm, so that in the sacral region, though there were two cords, there was only a single cartilaginous vertebral column.

3. Duval (6), speaking to his theory of polyspermia, states that following upon the polyspermia would be the apparition of two primitive streaks, which may take any position with regard to one another, at right angles, opposite, side by side, etc., and consequent upon their relative position to one another will be the position and amount of fusion of the future double monstrosity.

We are therefore of opinion that double terata result from the evolution, upon a single ovum, of two primitive grooves produced without bilateral segmentation of that ovum.

As to why two germinal areas should be induced in a single ovum, the most generally acceptable theory is that of Duval. In this theory, polyspermia is the chief, if not the only cause of redundancy of development. This theory is accepted, apparently in its entirety, by Laguesse and Bue in the article previously quoted; whilst Ballantyne (2) himself says, "The theory of polyspermia certainly affords a very good working hypothesis to account for the various kinds of double terata."

The theory of polyspermia is not, however, universally recognised as affording the correct explanation of the occurrence of two germinal areas upon a single ovum. Schultze (7), for example, rejects the theory in favour of the idea that diplogenesiis is caused by some condition of the ovarian ovum before impregnation, which condition he believes to be an incomplete cellular division.

Another argument which has been adduced against polyspermia as the cause of double terata, and which has never been satisfactorily answered, is this—if the entrance into a single ovum of two spermatozoa can produce double monstrosities, why cannot three spermatozoa so gain access and produce triple monstrosities, and so on *ad infinitum*?

Arguments such as these are difficult to answer, for in man, at least, no ocular proof can be adduced either in favour of, or against, polyspermia. These adverse views notwithstanding, it seems probable that polyspermia is a determining cause of double terata, for Gemmill (8) in a valuable paper on "The Vitality of the Ova and Spermatozoa of Certain Animals" says, "It is a remarkable fact that polyspermia and irregular development are more apt to occur in the case of ova that are fertilised immediately after being shed into sea-water, than in those which have been left to themselves for a little, *e.g.* for from one to four hours before fertilisation is attempted. Apparently the short interval gives them time to round off their circumference, and allows their peripheral layer to become accustomed to the medium of sea-water. . . . As is well known, in the normal fertilisation of the sea-urchin egg, immediately after the entrance of the first spermatozoon head, the peripheral layer of the ovum throws off a delicate but firm membrane—the membrane of fertilisation—which effectually prevents the entrance of additional spermatozoa. In well-marked cases of polyspermia this membrane is never formed. It is to be noted, however, that when perfectly fresh ova are taken from urchins that are perfectly ripe, immediate fertilisation may be effected without the occurrence of more than occasional cases of polyspermia. But whenever the ova are taken from a gland that is either immature or half spent, more cases of polyspermia occur with immediate than with delayed fertilisation."

Gemmill's remarks seem to suggest not only that polyspermia is a determining factor in irregular development, but also that the condition of the ovum has to be taken into account in the determination of monstrosities. It may therefore be that cases of triple monsters are unknown, because the ovum, being a mononuclear structure, cannot possibly tolerate, for germinal processes, more than two spermatozoa, consequently double monstrosities only occur. On this theory, which is merely adduced as a tentative reply to the argument as to why three spermatozoa do not gain access to an ovum and so produce triple monsters, triple monstrosities *would* result in the event of polyspermia occurring in a polynuclear human ovum, a contingency so improbable as to be outside the laws of chance.

It seems to us, therefore, from our own observations and from a study of the works of others, that it is not improbable that double terata result from polyspermia occurring in a mononuclear and single ovum, the ovum

itself playing, in an as yet undiscovered way, some pathological part, and that fertilisation having occurred in this manner, development proceeds without bilateral segmentation.

Explanation of the Variations recorded.—Passing now to the consideration of the embryological errors which resulted in the various abnormalities in the case herein recorded, it may be stated that the intestinal variations of the single duodenal tube, the single jejunum, and the hepatic and pancreatic variations are all alike due to the development of the two twins from a single ovum, with but one yolk sac between them, as is fully explained in Berry's paper (1).

The explanation of the remarkable cardiac variations is more difficult, but is probably as follows:—

From the description which has already been given, it is obvious that the apparently single heart has in reality resulted from the partial fusion of two originally distinct tubular hearts. The fusion of the two inferior venæ cavæ to form a single structure further shows that the fusion of the two originally distinct tubular hearts has been most marked in the region of the sinus venosus, whilst the greater imperfections in the auricles of the right twin and the absence of the superior vena cava show that the fusion has affected the right twin more than the left.

The abnormalities in the heart of the left twin, namely, the incomplete separation of the two ventricles and the failure of the inferior cava to open into the right auricle, are due, the first to failure in the development of the *pars membranacea septi*, and the second to the fusion already described as having occurred in the region of the sinus venosus.

In the heart of the right twin the variations mentioned were:—

1. The inversion of the heart.
2. The incomplete separation of the ventricles.
3. The fusion of the tricuspid and mitral orifices.
4. The absence of the superior venæ cavæ.
5. The fusion of the two inferior venæ cavæ.

The inversion of the heart is referable to the V-shaped bend made under normal conditions by the ventricular part of the embryonic tubular heart to the right having had to take place to the left on account of the presence, on the right side, of the heart of the other twin.

The incomplete separation of the ventricles and the fusion of the tricuspid and mitral orifices is due to failure in the development of the *pars membranacea septi*, and of the septum intermedium, which last, under normal conditions, "projects like a stopper into the auricular canal, and divides the latter into the two auriculo-ventricular orifices, and also grows down beyond that canal to meet the uprising ventricular septum."

Passing, in the last place, to the explanation of the variations in the great vessels, it may be stated that what might have been a difficult task has been rendered easy by the admirable article on this subject by Professors Young and Robinson in Cunningham's *Text-Book of Anatomy* (9).

FIGURE 2 SCHEMATIC REPRESENTATION OF THE CARDIAC AND VASCULAR ABNORMALITIES

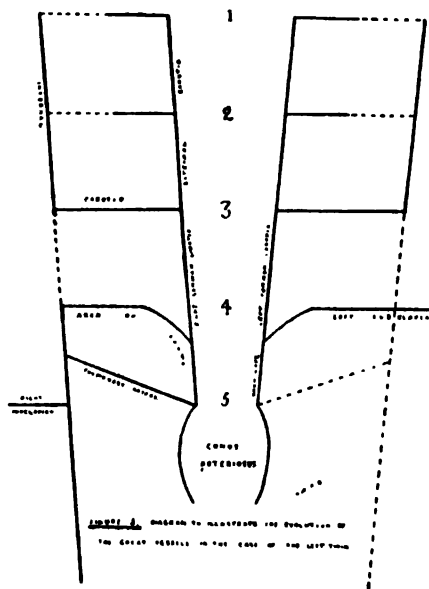
The fifth left cephalic aortic arch is entirely suppressed, whilst the whole of the fifth right aortic arch has remained as the pulmonary artery

The origin of the left subclavian and left common carotid arteries from a short innominate trunk is normal, with the exception that the vessels are necessarily inverted consequent on the inversion of the aorta,

that is to say, the innominate artery has here resulted from persistence of the ventral root of the fourth left arch instead of from the fourth right arch.

The origin of the right common carotid artery is also normal, with the exception of the inversion.

The right subclavian has apparently grown out from the dorsal aorta opposite, or caudal to, the fifth arch; at least, this seems to be the only possible explanation of the position of the vessel beyond the point of junction of the aorta and pulmonary arteries. If this explanation be the



correct one, then it is obvious that the origin of the vessel is abnormally far back.

The origin of the right and left pulmonary arteries from the descending thoracic aorta can only be explained on the assumption that they are abnormal outgrowths from that vessel, or else by supposing that bronchial arteries have replaced the pulmonary arteries. In view of the remarks made in *Quain's Anatomy* (10) that cases have been seen where "the right and left pulmonary arteries have received their supply of blood from the aorta," the former assumption is perhaps the more correct.

The abnormal origin of the hypogastric arteries as terminal branches of the abdominal aorta is presumably due to suppression of the common iliaes.

82 Variations presented by a Case of a Thoracopagous Lamb Monster

The great vessels of the right twin are normal, with the following exceptions:—

The whole of the fifth left cephalic aortic arch has persisted, with the necessary result that a junction has been thereby effected between the aorta and pulmonary artery.

The aortic origins of the right and left pulmonary arteries are to be explained as in the left twin.

The origin of the left subclavian has been shifted caudalwards as in the left twin.

The abnormal origin of the hypogastric artery is possibly, though not certainly, due to the suppression of one common iliac artery.

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OBSERVATIONS ON THE HEAD OF THE TIBIA.

By F. G. PARSONS, F.R.C.S.

THE object of this communication is to show that the form of the tibial head and spine depends largely on the arrangement of the contiguous soft parts.

The spine of the tibia always consists of two eminences placed side by side (α and δ , fig. 1), and separated by an oblique groove which runs backward and outward. Each of these eminences is the portion of the articular surface which is nearest the centre of the head of the tibia; and each, no doubt, rises up here because it corresponds to the intercondylar notch of



FIG. 1.—Head of left tibia. (3.)

the femur, for here the head of the tibia is relieved from pressure. As far as the femur is concerned, there is no reason why these eminences should not extend forward and backward as two long ridges, or, indeed, why they should not unite into one long ridge occupying the whole antero-posterior part of the mid-line of the tibial head. On looking at fig. 2, however, it will be seen that the external tubercle is limited anteriorly and posteriorly by the two horns of the external semi-lunar cartilage, while internally the anterior crucial ligament bounds it and lies in the oblique groove separating the two tubercles.

The internal tubercle is not bounded anteriorly and posteriorly by the semi-lunar cartilage, as the outer one is, but by the anterior and posterior crucial ligaments, which in this part of their course are parallel to one

another—their long axes running backward and outward. Owing to this obliquity it is evident that the antero-internal and postero-external parts of the internal tubercle of the spine are not pressed upon, and so this tubercle is prolonged forward and inward by a slight ridge, and backward and outward by a marked, oblique, rounded ridge, which I do not remember seeing described, but which, nevertheless, I believe is always present (β , fig. 1).

In front and behind this oblique ridge lie the anterior and posterior crucial ligaments, and it rises up just where the head of the tibia is relieved from the pressure of these ligaments in extension of the knee.

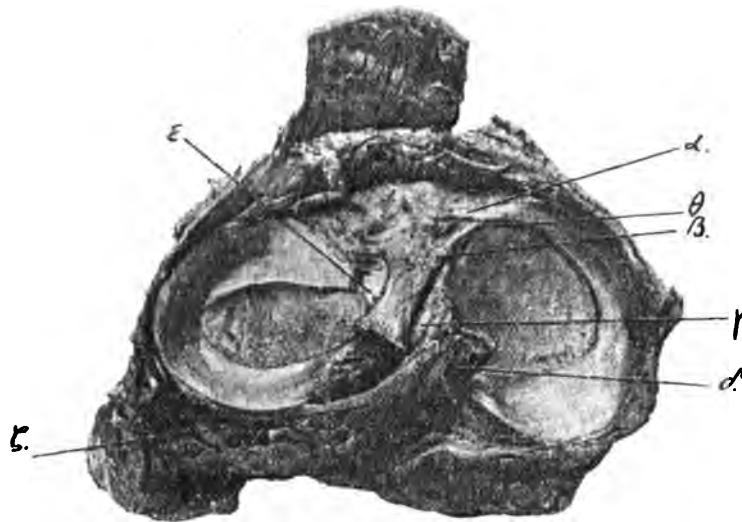


FIG. 2.—Left knee-joint with crucial ligaments *in situ*. (β .)

Along the summit of this ridge, as far as the internal tubercle, the posterior fibres of the posterior cornu of the external semi-lunar cartilage are attached (fig. 2, γ).

This is better seen when the crucial ligaments are reflected (fig. 3, γ).

On making a sagittal section of the fully extended knee, the ridge, with its superjacent fasciculus of the posterior cornu of the external semi-lunar cartilage, is cut almost transversely (fig. 4, γ), and its relation to the anterior and posterior crucial ligaments (β and δ , fig. 4) is shown.

This section, too, illustrates the amount of force which the posterior crucial ligament must exert in making its oblique groove during full extension of the knee, for it is arched with its convexity upward and backward.

To recapitulate, I should describe the spine of the tibia as consisting of two lateral tubercles, separated by an oblique groove, in the anterior part of which lies the anterior crucial ligament; while the internal tubercle is prolonged backward and outward by an oblique ridge, to which part of the posterior cornu of the external semi-lunar cartilage is attached. In addition to the spine, other bony eminences, marking the other fibrous attachments, may usually be seen if looked for.

The anterior cornu of the external semi-lunar cartilage is attached just in front of a slight oblique ridge (ϵ , figs. 1, 2, and 3) which runs forward and inward from the outer tubercle, and forms the anterior boundary of the



FIG. 3. — Left knee-joint with crucial ligaments turned back. (3.)

oblique groove (γ , fig. 1), which may be spoken of as the anterior crucial groove. The specimen (fig. 3) of the soft parts also shows that some of the anterior fibres of this cornu are continued into the outer part of the anterior crucial ligament; but this is well known. The main part of the posterior cornu of the external semi-lunar cartilage (fig. 3, a) is attached just behind a small ridge which runs across the long axis of the anterior crucial groove, dividing it into an anterior part for the anterior crucial ligament, and a posterior part, in which the anterior fibres of the posterior cornu of the external semi-lunar cartilage lie. This ridge is shown just in front of γ in fig. 1, and forms the summit of the anterior crucial groove which slopes downward from it both anteriorly and posteriorly.

The exact posterior attachment of the external semi-lunar cartilage is

therefore at least triple; the anterior fibres (α , fig 3) pass to this ridge in the anterior crucial groove, the more posterior fibres (γ , fig. 3) pass along, and are attached to, the oblique ridge separating the anterior and posterior crucial grooves, while the most posterior fibres of all (ξ , fig. 2) run up to the



FIG. 4.—Median sagittal section of knee-joint. (3.)

femur behind the posterior crucial ligament, as the ligament of Wrisberg. The anterior attachment of the internal semi-lunar cartilage is to the inner side of a slight ridge which is usually present in the mid-line of the head of the tibia, at the junction of its anterior and second quarters (fig. 1, η ; fig. 2 α).

The posterior cornu of the internal semi-lunar cartilage is attached to

the floor of the posterior crucial groove, where a small eminence (fig. 1, ξ) is sometimes present.

The tibial attachment of the anterior crucial ligament is indicated by a little knob (θ , fig. 1 and fig. 3) on the outer margin of the internal articular facet. From this the attachment runs transversely outward to about the mid-sagittal line of the tibial head. It will be noticed by referring to figs. 2 and 3 that this tubercle (θ) rises up just where it is relieved from the pressure of the anterior crucial ligament posteriorly, and the anterior cornu of the internal semi-lunar cartilage anteriorly.

The attachment of the posterior crucial ligament is seen in fig. 4: it is to the junction of the superior and posterior surfaces of the head, but I have not noticed that it is indicated by any special bony elevation. The best description of the head of the tibia with which I am acquainted is that in Humphry's *Human Skeleton*, but I cannot agree with the author in several points of exact detail; he does not, for instance, recognise the two crucial grooves or the oblique ridge separating them. I should not, however, have taken up time in discussing these points had I not believed that there is a definite mechanical reason for each one being as it is, and that they are good examples of a broad generalisation, which we all know but do not sufficiently impress upon our students—that bones are moulded by the contiguous soft parts much more than they mould those parts, and that every little elevation and depression has its meaning.

For the photographs I am indebted to my friend and pupil Mr Lupton.

NOTE ON A CASE OF ABNORMAL DISPOSITION OF THE
PERITONEUM. By Dr J. D. LICKLEY and Dr J. CAMERON.

THE following case from the dissecting-room of Manchester University presents some points of embryological importance. The subject was a male *æt.* 52; the cause of death was unassociated with the intestinal arrangement.

On opening the abdominal cavity the arrangement of the stomach, transverse colon, and great omentum was apparently normal. When the

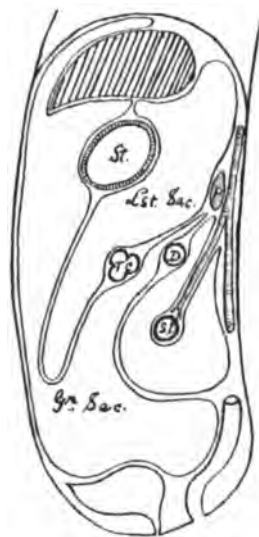


FIG. 1.

omentum was thrown upwards the small intestines were seen to be enveloped in a peritoneal sac distinct from the general peritoneal cavity. The sac was cut open transversely, and its connections were found to be as follows:—Its posterior wall was formed by peritoneum covering the posterior abdominal wall from the lower border of the pancreas to the sacral promontory. From this wall the peritoneum was reflected to form the mesentery of the small intestine. The line of reflection of the mesentery was practically parallel to the mid-dorsal line, and was situated to the left of the vertebral column. The anterior wall of the sac contained in its

upper part the third and fourth portions of the duodenum. The relationship of the superior mesenteric artery to the duodenum was therefore disturbed, the artery passing down in the layers of the mesentery *behind* the duodenum.

Laterally, the walls of the sac could be followed to the ascending and descending colons. On the right side the sac wall reached quite to the ascending colon, so that the wall of the sac was practically in the line of the ileo-colic junction, the terminal end of the ileum lying within the sac and the cæcum immediately outside. On the left side the sac wall was just short of the descending colon. A general laxity of the abdominal wall was shown by the presence of small fatty herniæ through both inguinal and femoral rings, and through the right obturator foramen.

The explanation of this condition is to be found in an abnormal process of development. In the rotation of the gut which results in the translation

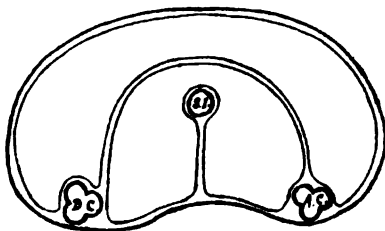


FIG. 2.

of the cæcum to the right side, and the splenic flexure to the left, the original mesentery which bound down these parts to the middle line of the posterior abdominal wall has been retained. This has been associated with a displacement of the mesentery of the small intestine slightly to the left side, so that the small intestine, instead of growing downwards and to the right below the mesentery of the large intestine, has grown down under cover of it. The wall of the abnormal sac has thus been derived from the original mesentery of the large intestine, and therefore consists of two layers (figs. 1 and 2). The transverse mesocolon has undergone the usual series of fusions, resulting in a normal adult form. The duodenum has not, however, been pushed against the posterior abdominal wall, as should normally occur. This failure has probably been associated with the presence of the superior mesenteric artery behind it. As a result, the duodenum is found enclosed between the layers of the original mesocolon (fig. 1).

Cleland¹ has recorded a case of an abnormal peritoneal sac enclosing

¹ *Journ. of Anat. and Physiol.*, vol. ii., 1868, p. 201.

the small intestines. In Cleland's specimen the greater portion of the anterior wall of the sac extended between the stomach and the transverse colon, and was derived from the peritoneum "on the concavity of the arch formed by the ascending, transverse, and descending colons." The transverse colon, accordingly, lay in the lower part of the anterior sac wall, whereas in our case the sac did not become exposed to view until the transverse colon and great omentum had been turned upwards. Further, in Cleland's case there was a small opening in the anterior wall of the sac, immediately above the ileo-colic junction; but in our specimen there were no evidences of an aperture in any part of the sac wall.

JOURNAL OF ANATOMY AND PHYSIOLOGY

THE MECHANICAL SUPPORTS OF THE PELVIC VISCERA.

By Professor A. MELVILLE PATERSON, M.D., *Liverpool*.

IN these days of frequent operation for the removal of pelvic viscera, and of plastic operations on the pelvic floor, it is necessary for surgeons to possess an exact knowledge of the mechanical supports of the pelvic viscera, and for anatomists to reconsider their conceptions of these relationships.

One has no hesitation in asserting at the outset that the accounts of the pelvic fascia given in the standard text-books on anatomy are in many respects erroneous, and that there are important features of the fascia in relation to the viscera and floor of the pelvis that have escaped the notice of even such competent observers as Berry Hart (4) and Peter Thompson (8).

The most accurate account of the disposition of the fascia that one has met with is that by Stoney (6). But even here, while the main conclusions arrived at in this paper are actually figured, there is no mention in the text of what one regards as the essential feature in the arrangement of the fascia.

The Pelvic Floor.—In order to have a proper conception of the method of support of the pelvic viscera, we need at the outset a precise knowledge of what constitutes the pelvic floor. Just as from the perineal aspect the floor of the pelvis may be divided into a *posterior* or dorsal part, containing the *anal canal*, surrounded by the ischio-rectal fossæ and characterised by looseness and distensibility; and an *anterior* or ventral part—the *urethral triangle*—containing the *genito-urinary passages*, supported by the triangular ligaments and the root of the penis, and characterised by firm fixation to the pubic arch; so from the abdominal aspect also, the floor of the pelvic basin is similarly constituted, so as to provide a *posterior* or dorsal portion—a *rectal channel*—in which the rectum lies loose; and an *anterior* or ventral portion, containing the *genito-urinary passages*, which are firmly fixed to the pelvic floor and walls by an investment of pelvic fascia.

The structures which constitute the pelvic floor are (1) the symphysis

pubis; (2) the triangular ligaments enclosing the membranous urethra, compressor urethræ, pudic vessels and nerves, etc.; (3) the "central point of the perineum" or "perineal body" (Symington), the mass of tissue intervening between the base of the triangular ligaments and the front wall of the anal canal, and containing the fibres of the bulbo-cavernosus, external sphincter ani, transversus perinei, and recto-urethrales muscles; (4) the levatores ani and external sphincter ani muscles, on either side of the anal canal; and (5) the "ano-coccygeal body," between the anal canal and the coccyx, also containing muscular fibres of the external sphincter ani, recto-coccygeus and (particularly) levator ani muscles.

The points to which one would direct special attention in the following account are the disposition and relations of the pelvic fascia to the pelvic viscera as they are approaching or passing through the pelvic floor.

Materials.—Besides numerous dissections of the pelvic contents in the human subject (male and female), one has also utilised human fetuses at full term; and has controlled and amply confirmed one's observations by dissections of the following mammals:—

Kangaroo (male); horse; duiker bok (*Cephalophus Grimmii*) (female); Persian goat; 3 chimpanzees (2 male, 1 female); and porcupine (female). For most of the animals named I am indebted to Dr H. O. Forbes, Director of the Free Public Museums, Liverpool.

I have further to acknowledge my indebtedness to Dr T. B. Grimsdale for opportunities of observing the disposition of the parts in the living subject, during operations on the pelvic floor performed by him at the Liverpool Royal Infirmary.

Method.—One's first method was by dissection from above. The pelvis was sawn across obliquely (parallel to the pelvic brim), in a line just above the great sacro-sciatic foramen. This section of the pelvis gave more room for the examination of the pelvic viscera and floor. The peritoneum was stripped off the rectum and bladder and the extra-peritoneal tissue was then removed. By this means we can easily demonstrate the essential features of the pelvic fascia in relation to the viscera.

It was found that a still better mode of demonstrating the arrangement by which the pelvic viscera are supported was by means of a mesial (*sagittal*) section, through the symphysis pubis, pelvic viscera, and vertebral column. One could then most easily detach the peritoneum and extra-peritoneal tissue, and clearly demonstrate the relations of the pelvic viscera not only to the pelvic fascia, but also at the same time to the pelvic floor.

The Pelvic Fascia.—The pelvic fascia in the first instance forms a membranous covering for the muscles of the pelvic walls,—continuous except for the perforations for the obturator nerve and the parietal branches of the

internal iliac artery. It is continuous with the periosteum over the pelvic surface of the pubis, and is attached to the ischial spine.



FIG. 1.—Mesial section of the pelvis in the human subject (male).

This layer is strictly parietal. Sweeping downwards over the obturator internus, pyriformis, and ischio-coccygeus muscles, it clothes the pelvic

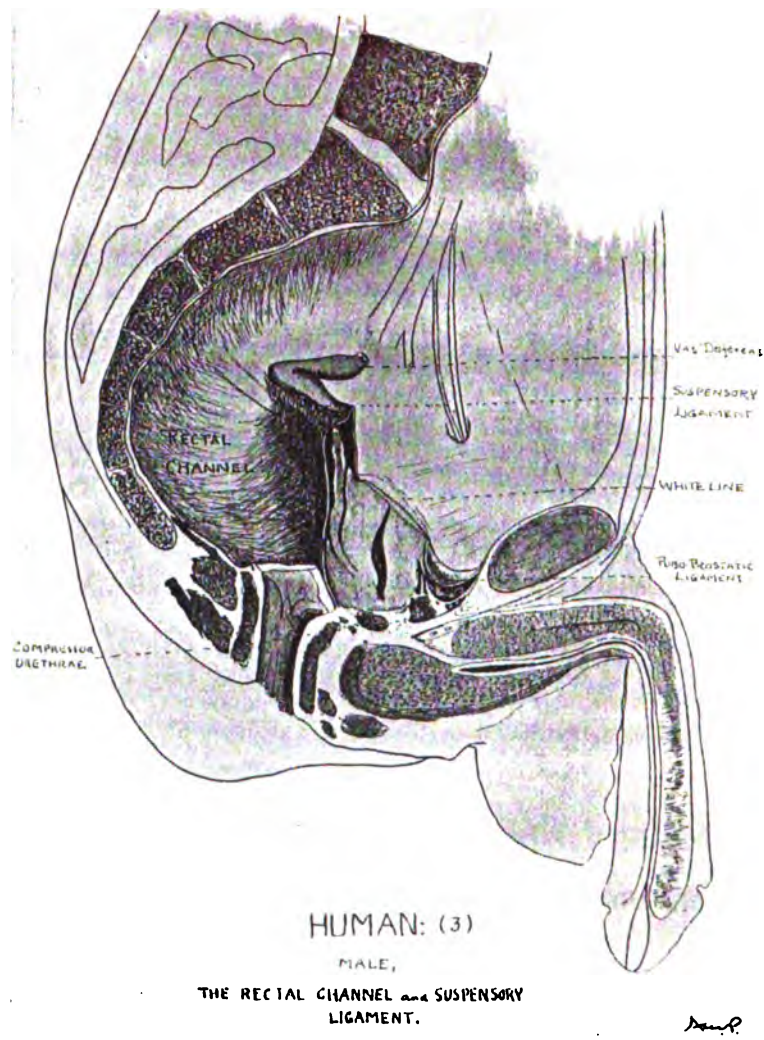


FIG. 2.—Mesial section of the pelvis in the human subject (male).

surface of the levator ani, and ultimately gains an attachment to the pelvic floor (1) to the posterior layer of the triangular ligament in front of the levator ani, (2) to the central point of the perineum, (3) to the commence-

ment of the anal canal, and (4) to the ano-coccygeal body, where it passes over the insertion of the levator ani to the opposite side.

At the anterior border of the levator ani it is continuous with the posterior layer of the triangular ligament; at its posterior border it is continuous with the fascia covering the pelvic surface of the ischio-coccygeus.

Over the origin of the levator ani the fascia presents *several thickened bands*, of which the most important is the "white line" which stretches like a bow-string between the ischial spine and the back of the pubic symphysis. Associated with it are two or more additional bands, one of which passes forwards in front of the obturator hole; another passing upwards



HUMAN: (5)

The Sheath of the PROSTATE.

Ames?

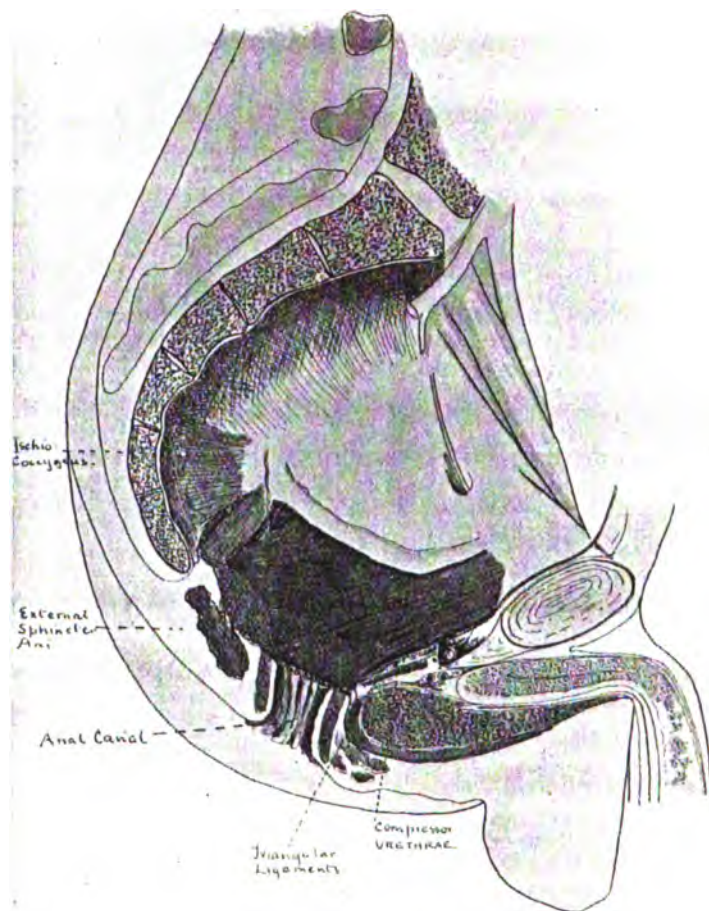
FIG. 3.—The sheath of the prostate gland.

to the border of the great sacro-sciatic notch. These bands are well shown in Waterston's stereoscopic *Atlas of Anatomy* (section ii., No. 6).

The white line and these additional bands have no definite connection with the origin of the levator ani muscle. As is well known (Thompson (9)) the fibres of the muscle often pass up to a level higher than that represented by the white line.

The real significance of this thickening of the pelvic fascia is in connection with the formation of the suspensory ligaments of the genito-urinary organs to be referred to later.

One would suggest that the term "visceral" pelvic fascia should be dropped altogether, as confusing and misleading. The only viscera invested by pelvic fascia are the genito-urinary organs, the prostate, vesiculæ



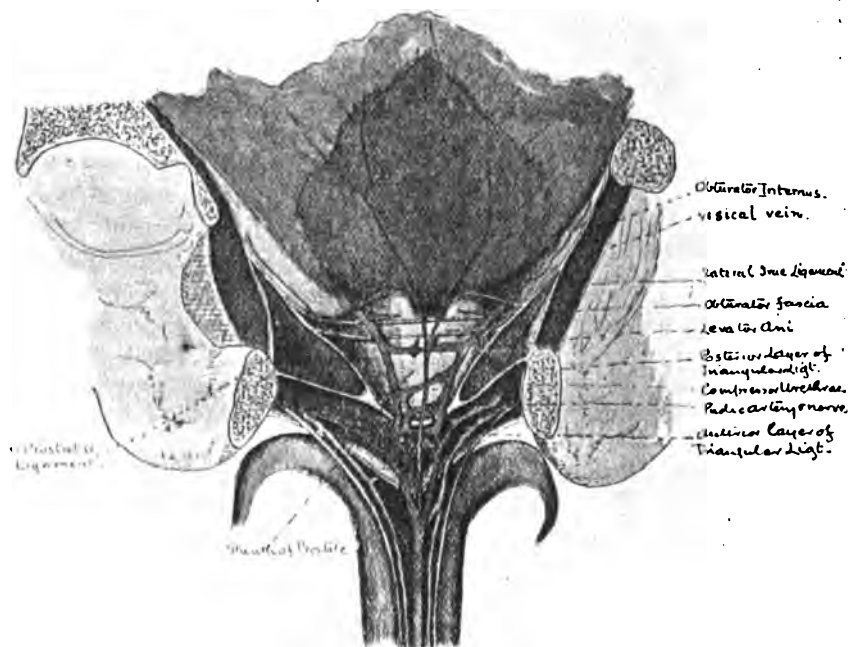
HUMAN: (6)

THE LEVATOR ANI.

FIG. 4.—The muscles of the pelvic floor and the relation of the levator ani to the triangular ligaments.

seminales and vasa deferentia in the male, and the vagina and urethra in the female; and these are invested and suspended by a special fold of the pelvic fascia, for which I venture to suggest the term "suspensory ligaments."

Whether the dissection is made from above or after mesial section of the pelvis, it is perfectly obvious that the rectum and the genito-urinary passages are related to the pelvic fascia in quite different ways. The rectum descends to the pelvic floor, where the anal canal begins, invested by a dense layer of extra-peritoneal tissue loosely adherent to it and devoid of fat; it occupies a channel lined by pelvic fascia, which sweeps down over the levator



THE PROSTATIC PLEXUS.
HUMAN: (7)

FIG. 5.—The prostatic plexus of veins.

ani on each side so as to gain an attachment to the pelvic floor at the commencement of the anal canal. This arrangement is fully described by Stoney (6).

The anterior wall of this rectal channel is formed by the special layer of pelvic fascia which invests the genito-urinary passages.

The rectum therefore occupying the posterior or dorsal section of the pelvis, is altogether free and separate from adhesions of the pelvic fascia: it lies loose in its special channel, clothed by extra-peritoneal tissue, and is

free to distend and collapse. The shape of the rectum is, however, modified, as we shall see later by the disposition of the suspensory ligaments of the genito-urinary organs.

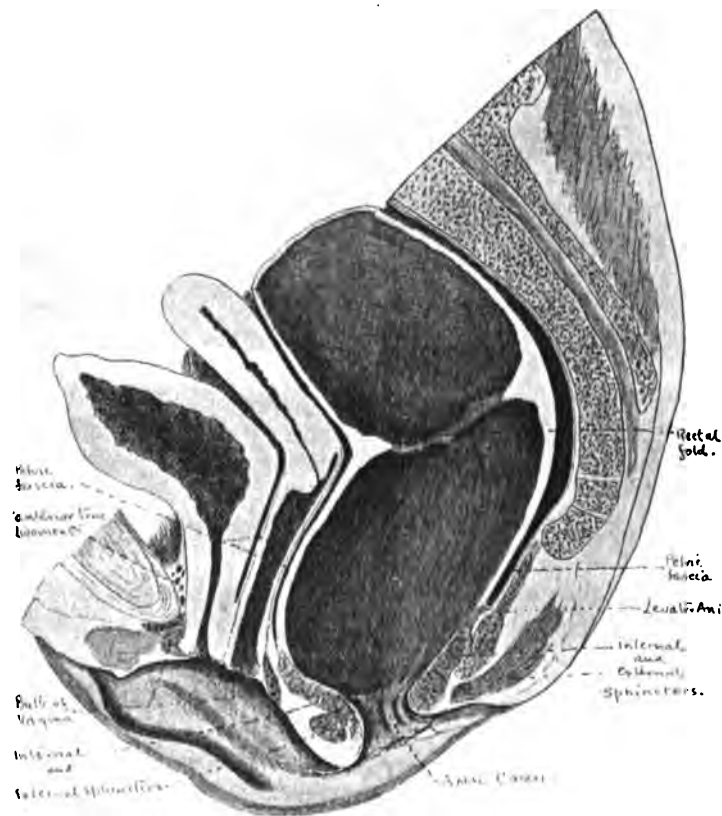
The suspensory ligament of the genito-urinary organs arises from the general fascia as a crescentic fold in the neighbourhood of the ischial spine (fig. 2). The posterior edge of the fold is concave, and is pierced by vessels and nerves, and nearer the middle line by the vas deferens. Further forwards this fold divides at its attached edge into two separate layers, which, arising independently from the general fascia covering the levator ani on its pelvic surface, pass inwards; one (anterior) arising from the white line, passes over the side of the prostate to the junction of that organ with the bladder; the other (posterior) passes across the back of the prostate, and separates it from the rectum. This posterior layer extends upwards so as to form a sheet of investment for the vesiculæ seminales and vasa deferentia. This is rather in the form of a septum than a sheath: it separates the vesiculæ seminales and bladder from the rectum, but allows the vesiculæ seminales to rest directly against the bladder. It forms the layer of pelvic fascia bounding the rectal channel in front. It is attached to the floor of the pelvis—to the perineal body—between the base of the triangular ligament and the origin of the anal canal, just above the internal sphincter ani.

The anterior layer of the fold is synonymous with the "lateral ligament of the bladder." It contains a distinct layer of muscular fibres in its more anterior portion (Cleland and Mackay (2), Thomson Walker (3)), and encloses a channel or sheath for the vesical vein on each side, which eventually pierces the crescentic margin of the fold and joins the internal iliac vein. Tracing this layer forwards, it becomes continuous with the "pubo-prostatic ligament" or "anterior true ligament" of the bladder. As already pointed out by Richardson (5), this band of the fascia is separable into several layers by a plexiform arrangement of veins formed by the subdivision of the dorsal vein of the penis joined by vesical and prostatic veins, and by communications with the internal pudic vein. From this plexus the vesical vein arises on each side.

The pubo-prostatic ligaments are extremely short, and the layers of fascia of which they are composed are inextricably blended below the symphysis pubis with the sub-pubic ligament and the posterior layer of the triangular ligament; the several layers radiating from this origin, after a short course unite with the anterior layer of the suspensory ligament over the front of the prostate gland.

The sheath of the prostate gland (fig. 3) is therefore formed:—in front, by the anterior layer of the suspensory ligament, with the addition of the bands of the pubo-prostatic ligaments; posteriorly by the posterior layer

of the suspensory ligament; laterally in man it is formed by the general



HUMAN: (8)

RELATION OF PELVIC FASCIA TO PELVIC VISCERA.

VIRGIN FEMALE.

FIG. 6.—Mesial section of the pelvic cavity in the human subject (virgin female).

pelvic fascia covering the pelvic surface of the levator ani muscle; and below it is completed by the posterior layer of the triangular ligament.

There are great differences in the separability of the sheath from the

proper capsule of the gland, possibly dependent on differences in the prostate itself. In many cases it is a matter of ease to separate the sheath; the chief adhesions being in the middle line on its anterior surface, and along the lateral borders of the gland.

It is important to note that the vascular plexus does not, as stated by many writers (including Freyer (3)), lie between the sheath and the capsule proper, but is placed between layers of the pelvic fascia which constitute the sheath of the gland. The vessels are most obvious in front of the prostate, among the layers of the pubo-prostatic ligament; and posteriorly in the crescentic fold of the suspensory ligament on each side of the prostate gland. As already stated, the vesical vein runs in a sheath formed in the "lateral true ligament" on each side of the base of the bladder.

In the female (figs. 6 and 7) the arrangement of the fascia is essentially the same. A crescentic fold extends across the pelvic cavity, forming on each side the suspensory ligament of the vagina and urethra. Behind it is a capacious rectal channel, lined by the pelvic fascia as in the male, in which the rectum lies loose and free down to the pelvic floor and the beginning of the anal canal.

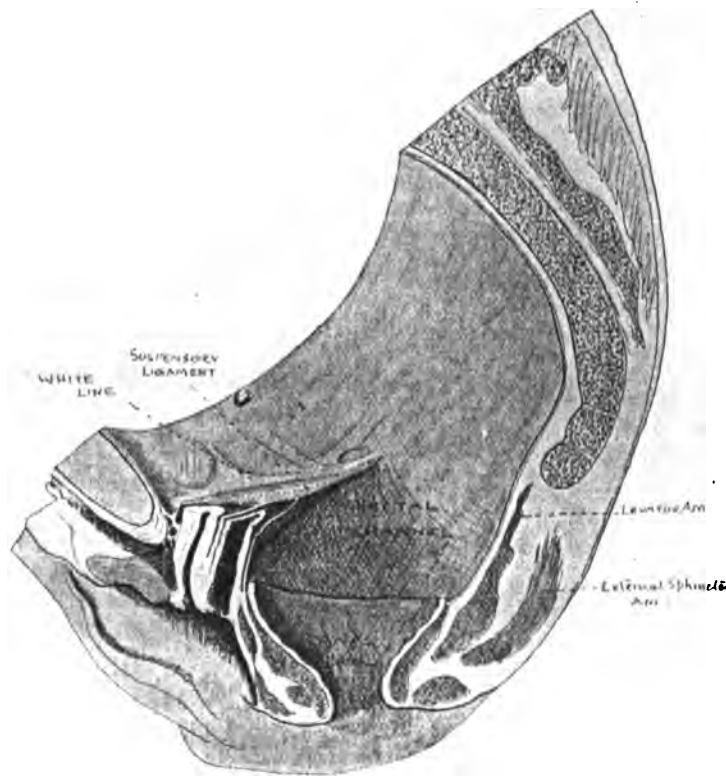
The suspensory ligament in the female divides, as in the male, into anterior and posterior layers to enclose the lower parts of the urethra and vagina, so that the bladder and uterus are left as intra-pelvic organs. The anterior layer, as in the male, has a lateral attachment to the white line, forms a sheath for the vesical vein, and constitutes the "lateral true ligament" of the bladder. It is continuous in front with the "anterior true ligament," which consists of radiating bands of fascia extending from the subpubic ligament to the urethra, and containing between the layers a plexus of veins. The posterior layer passes across behind the vagina: it intervenes between the vagina and rectum, and is attached below to the pelvic floor, behind the vagina and in front of the commencement of the anal canal.

In addition to these main layers, there is also in the female an intermediate subordinate layer of the suspensory ligament, which extends across the middle line between the lower parts of the urethra and the vagina, and is attached below to the posterior layer of the triangular ligament.

In both male and female this suspensory ligament is extremely vascular: along the upper and lateral part of the prostate in the male, and alongside the lateral fornix of the vagina in the female.

The ureter lies altogether above the ligament, and clings to the peritoneum when that is stripped off. The recto-vesical fold of peritoneum in the male, and the recto-uterine fold in the female, are also above the ligament, and correspond to it in a general way; but they are separated from it by the extra-peritoneal tissue and the internal iliac vessels.

Like the structures in the perineum, the viscera passing through the pelvic floor have a different disposition in respect of their mechanical supports. The genito-urinary passages are firmly fixed by their suspensory



HUMAN: (9)

VIRGIN FEMALE.
THE RECTAL CHANNEL and SUSPENSORY LIGAMENT.

FIG. 7.—The pelvic fascia in the human subject (virgin female), after removing the bladder, uterus, and rectum.

ligaments: the rectum descends in a rectal channel, and is altogether free from adhesions of the pelvic fascia.

The rectum is modified in shape by its relation to these suspensory ligaments. In many cases a permanent fold of the whole rectal wall (figs. 1 and 6) is produced by the crescentic margin of the ligament, dividing the

rectum into an upper portion which is related to the back of the bladder and vesiculæ seminales in the male, or the upper portion of the back of the vagina and the pouch of Douglas in the female; and a lower portion (the rectal ampulla) which lies against the back of the prostate in the male, or the posterior part of the lower surface of the vagina in the female. This lower part of the rectum may be distended so as to occupy completely the wide cavernous space below and behind these suspensory ligaments.

CHIMPANZEE.



FIG. 8.—Mesial section of the pelvis of the chimpanzee, showing the rectal channel and suspensory ligament.

COMPARATIVE ANATOMY.

Having satisfied one's self of the constancy of the arrangement of the pelvic fascia in the human subject described above, investigations have been made into the manner of support of the pelvic viscera in certain mammals.

Speaking generally, the mechanical supports of the pelvic viscera are essentially the same in the animals examined as in the human subject.

The rectum passes to the pelvic floor, where it gives rise to the anal canal. In its course it occupies a rectal channel bounded laterally by the fascia covering the pelvic surface of the levator ani, and inferiorly by the posterior layer of the suspensory ligament of the genito-urinary organs. It is free from adhesion of the pelvic fascia, from which it is separated by the extra-peritoneal tissue.

The genito-urinary organs are slung and ensheathed by a suspensory ligament, which possesses the same crescentic (superior) border as in man (pierced by vessels and nerves).

In the chimpanzee (fig. 8) the ligament has the same disposition as in

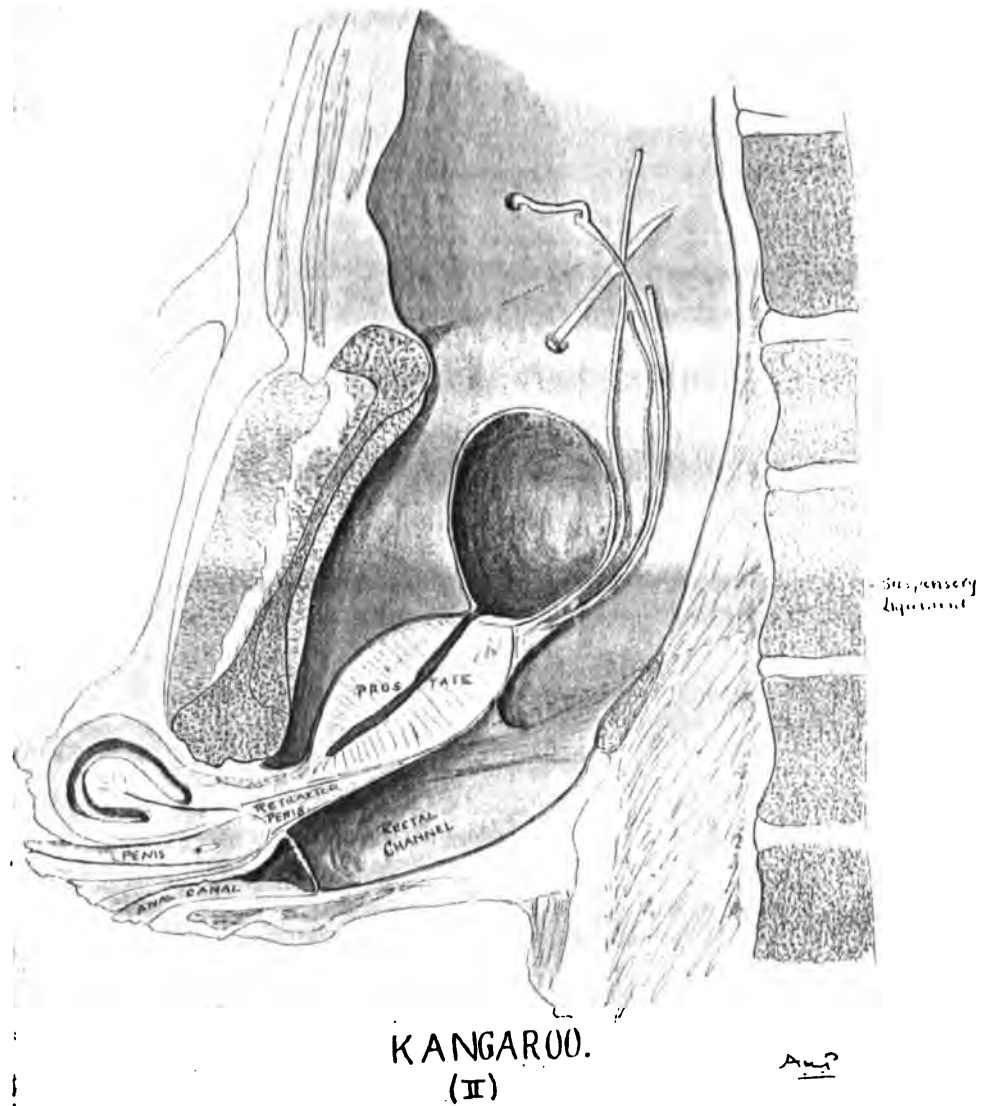


FIG. 9.—Mesial section of the pelvis in the kangaroo (male), showing the rectal channel and suspensory ligament of the pelvic fascia.

man: in other words, the posterior and anterior layers, which invest the genito-urinary passages, have an independent and separate origin from the fascia covering the pelvic surface of the levator ani muscle.

In the other animals dissected—horse, duiker bok, Persian goat, and porcupine (figs. 9, 10, and 11)—the suspensory ligament arises *as a single*

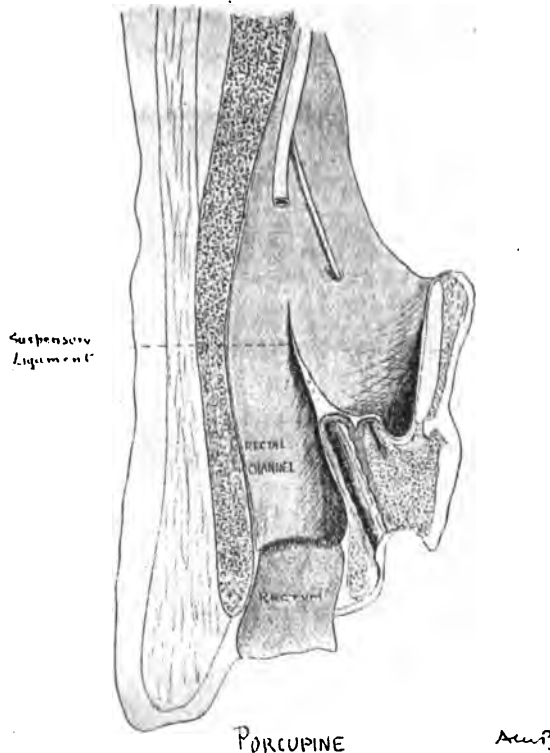
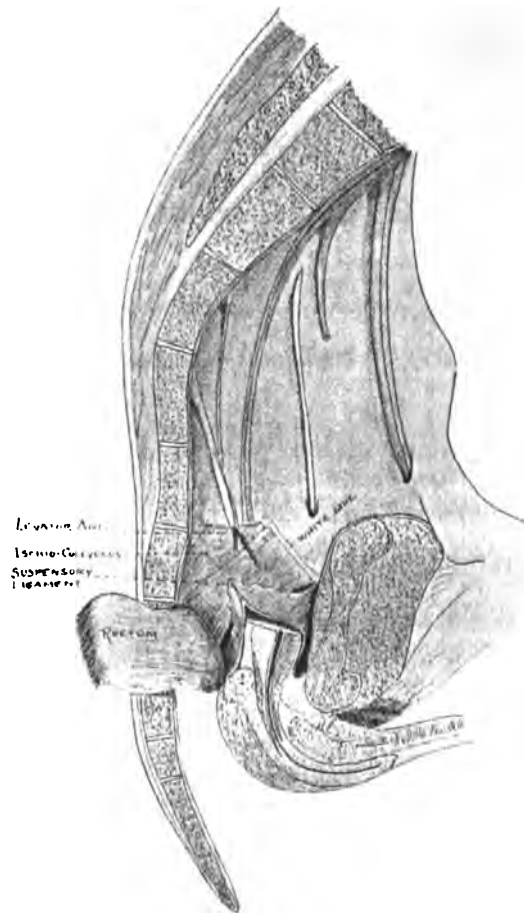


FIG. 10. — Mesial section of the pelvis of the porcupine, to show the rectal channel and the suspensory ligament of the pelvic fascia.

layer from the general fascia of the pelvis, and subsequently separates to form the investing sheath of the genito-urinary organs.

Differences in the arrangements in the several animals were due to the differences in the development of the levator ani muscle. In the duiker bok, horse, Persian goat, and porcupine, the muscle is small and has no pubic origin; in the kangaroo (*Macropus giganteus*) it is well developed, and has an extensive origin from the whole length of the pubis. In the former examples, the fascia enclosing the levator ani becomes continuous at the ventral

border of that muscle with the fascia lining the obturator internus, and the suspensory ligament has therefore in such cases an additional attachment to this fascia. In the case of the kangaroo the levator ani extends to the



PERSIAN GOAT.

FIG. 11.—Mesial section of the pelvis of the Persian goat.

middle line in front, and so the suspensory ligament arises in its whole length from the fascia covering the muscle. In the kangaroo, further, a well-defined retractor penis muscle (fig. 9) extends between the rectum and levator ani, enclosed in the fascia covering the pelvic surface of the latter muscle.

It has been stated that the white line is not generally present in mammals (Thompson (8)). I find it not clearly defined in the kangaroo (though the fascia is obviously thickened at the point of origin of the genito-urinary suspensory ligament). It is absent in the horse and porcupine, present in the duiker bok and Persian goat, and well defined in the chimpanzee (in which, in one instance, additional bands passing forwards to the pubis and upwards to the great sacro-sciatic notch could be readily made out). It appeared in all cases in which it was present to be a strengthening band of the fascia for the attachment of the suspensory ligament.

The observations made on the animals named, without going into prolix and unnecessary detail, fully confirm the statements made with regard to the mechanical supports of the pelvic viscera in the human subject.

One's excuse for drawing attention to these points is (1) to correct a serious misconception which pervades the descriptions of the pelvic fascia in anatomical writings; and (2) to give a rational explanation of the relations of the pelvic viscera to the pelvic floor. The surgeon is now dealing with this region in a way that is not compatible with the descriptions in anatomical text-books. It is an example of practice outgrowing dogma. This investigation has been an attempt to revise our creed, and bring it into accord with things as they are.

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VARYING POSITIONS OF THE CARPAL BONES IN THE
DIFFERENT MOVEMENTS AT THE WRIST. By HENRY M.
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Dublin.*

PART I.

EXTENSION, ULNAR, AND RADIAL FLEXION.

THE complicated structure of the carpus, and the variety of the movements which take place among its constituent bones, have received the attention of a considerable number of anatomists. Henke, Meyer, Bryce, H. Virchow, and Fick, among others, have within recent years published papers upon the subject. Some authors, such as Bryce¹ and Fick,² have studied the living hand by means of the Röntgen rays. Admirable results may be obtained in this way for those positions of the joint in which the hand and forearm are in the same plane. Realising the difficulty of obtaining satisfactory pictures of dorsal and volar flexion of the hand, H. Virchow adopted another method. The hand of a dead subject is fixed in any desired position, and then frozen. While still in the frozen condition the soft tissues are dissected off down to the bones; a plaster cast is now taken of the bones as they lie in position, and this cast serves as a mould into which they can be fitted after maceration. In this way Virchow obtained a series of exceedingly useful and interesting preparations. There are considerable difficulties in using this method in our climate: I have therefore adopted a modification which I have found to give very satisfactory results.

The method adopted was as follows:—A fresh and suitable subject having been chosen, the hand was placed in the desired position. In each case the forearm was supinated as far as possible. When the back of the hand and forearm were in one plane, viz., in extension, ulnar, and radial flexion, the part was pinned to a board upon which the dorsal surface rested. When it was desired to study dorsal or volar flexion, a splint of wood or a mould of plaster was made on which the part could be placed in the required angle of flexion. The hand having been placed in position,

¹ *Journal of Anatomy and Physiology*, 1906.

² *Verhandlungen der Anat. Gesellschaft*, 1901.

formalin in full strength was injected through the brachial artery. After about a week's time the hand, now quite hard and stiff, was removed from the body by sawing through the forearm. By careful dissection its palmar surface was denuded of soft tissue down to the bones. These latter were made as clean as possible, special care being taken not to injure the articular cartilages where exposed. For future reference careful measurements were taken, and a stereoscopic photograph was prepared of the bones as they lay held firmly in place by the ligaments and soft tissues on the dorsal aspect of the hand and wrist. Plaster of Paris was now poured over the exposed bones, but the mould when set was not removed. The specimen having been turned over, the dorsal surface was dissected in the same manner as the palmar had been; the plaster mould retaining the bones in proper position. Finally, the bones having been measured and photographed from the dorsal aspect, plaster of Paris was applied, and a mould prepared. The bones were now enclosed between palmar and dorsal moulds. The dorsal cast was removed first; it separated quite easily. From the palmar one the bones had to be picked off separately. By fitting the isolated and thoroughly cleaned carpal bones into their proper position in the moulds, it is possible to obtain exceedingly striking and faithful representations of their normal position either from the dorsal or from the palmar aspect. It was found necessary, however, to keep the bones moist, because if they are permitted to dry some shrinking takes place, and their coaptation is no longer quite so perfect. The drawings and the measurements given in this paper were made while the bones were kept moist. Plaster of Paris models of the bones in their moulds were also made, and these when painted are almost as useful as the original preparations.

DESCRIPTION OF PREPARATIONS.

In all, ten wrist-joints were taken from five subjects; and the following is a list of the positions in which each wrist-joint was fixed before examination:—

- Subject 1. Right wrist in extension.
Left wrist in dorsal flexion.
- „ 2. Right wrist in slight ulnar flexion.
Left wrist in volar flexion.
- „ 3. Right wrist in ulnar flexion.
Left wrist in radial flexion.
- „ 4. Right wrist in semi-dorsal and ulnar flexion.
Left wrist in semi-dorsal and radial flexion.

**Subject 5. Right wrist in semi-volar and ulnar flexion.
Left wrist in semi-volar and radial flexion.**

Right Wrist in Extension.

The wrist and hand are in what may be called the "straight position," and the long axis of the third metacarpal bone nearly corresponds to



FIG. 1.—Right wrist in extension, seen from the front.



FIG. 2.—Right wrist in extension, seen from behind.

that of the forearm. Fick selects this as a standard position with which others may conveniently be compared.

Seen from the Front (fig. 1).—A slight amount of dorsal flexion is suggested owing to the fact that the majority of the carpal bones project forwards. The most anterior point is the upper end of the ridge of the trapezium, which lies 2 mm. in front of the tubercle of the scaphoid. The latter and the pisiform are equally prominent, and the apex of the

hook of the unciform is slightly more posterior. The lunar is on a somewhat anterior plane to the os magnum.

With regard to the carpal bones, we notice that the various articular surfaces are not so tightly or so accurately applied to one another as one might at first expect. In some cases articular surfaces are exposed, or the bones are separated from one another by intervening spaces. The individual bones of the second row are so tightly bound together by their strong ligaments that they may almost be looked upon as one piece, and their articular facets are so accurately applied that no articular surface is exposed. Similarly, the articular surfaces of the bones of the first row are accurately applied to one another; but a considerable amount of gliding movement is possible between the scaphoid and lunar, owing to the laxity of the ligaments uniting them together.

The tubercle of the scaphoid lies 1 cm. below and .5 cm. internal to the radial styloid, and points directly forwards. The lower end of the ulna is widely separated from the carpus, the intervening interval being filled up in life by the triangular fibro-cartilage and by the ligamentous fibres (internal lateral ligament) stretching from the styloid process to the pyramidal bone. These fibres are lined on their deep aspect by synovial membrane, and are applied to the supero-internal surface of the pyramidal bone. The radial edge of the articular surface of the radius and of the scaphoid bone are seen to correspond accurately.

The anterior margin of the lower end of the radius usually shows a slight but marked depression, which indicates anteriorly the position of the ridge separating the inferior radial articular surface into its two facets. In the extended position of the wrist, the ulnar extremity of the scaphoid most reaches this ridge. The ridge itself and the lunar facet of the radius, over an area measuring 3 mm., are related to the superior scapho-lunar ligament. The superior surface of the lunar bone is tightly applied to the radius for two-thirds of its extent, and to the triangular fibro-cartilage for the remaining third. Where the lunar articulates with the radius, a narrow strip of articular cartilage is exposed on the palmar aspect in the extended position of the wrist. The long axis of the lunar, if produced, would pass through the tubercle of the scaphoid. The ulnar extremity of the superior surface of the scaphoid is situated rather posteriorly; the long axis of the bone is therefore directed from above downwards, forwards, and slightly to the radial side. At the upper end of the scaphoid a strip of articular cartilage, measuring 5 mm. on an average in vertical extent, is exposed. This diminishes towards the ulnar side. A slight interval separates the articular surfaces of the scaphoid and radius in the region of the styloid process of the latter.

The long axis of the pyramidal is directed downwards and to the ulnar side. In this position of the wrist, the pisiform bone is separated 1 mm. from the pyramidal.

Of particular interest is the disposition of the bones at the midcarpal joint. Beginning at the radial end of the articulation we find that the articular facets of the trapezium, trapezoid, and scaphoid are so accurately applied in front, that no intervening spaces and no articular cartilage is exposed. The scaphoid and os magnum are also in close and accurate apposition, and the plane of the joint formed between them is vertical. The scaphoid articulates with that part of the os magnum which lies on the radial side of the radial ridge on the head. Passing now to the articulation between the lunar and the os magnum, we find them closely applied; but the lunar fails to cover the entire articular surface of the os magnum, and hence a strip of the articular cartilage of the head is exposed. This measures 4.5 mm. vertically. The lunar articulates with that part of the head of the os magnum which intervenes between the radial and ulnar ridges. The upper pointed end of the unciform does not reach the lunar (Bryce), but a somewhat quadrilateral interval is left between the two bones. This interval measures 3.5 mm. across, and is bounded at the sides by the os magnum and the pyramidal bone. Reaching finally the interval between the pyramidal and unciform bones, we find that there is but little coaptation between the articulating surfaces. Only for 10 mm. to the ulnar side of the quadrilateral space mentioned above are the two bones accurately applied as seen from the front. Near the ulnar margin of the hand there is a wide interval between the pyramidal and unciform; this is bounded below by the concave articular surface of the unciform, but its upper limit is now articular and is formed by the pyramidal. The long axis of the os magnum will be noted to be vertical in the extended position of the wrist.

In the extended wrist *seen from behind* (fig. 2), the articular facets of each row of bones are seen to be accurately applied to one another; but at the radio-carpal and at the mid-carpal joints a greater want of coaptation may be noted among the articulating bones. A notable feature is a groove or furrow which runs across the back of the carpus at the junction of the two rows. This furrow is deepest at the radial side, where it can easily be felt in the living subject; although, since it is bridged over by different tendons, and filled up by the ligaments of the wrist, its depth is not fully appreciated. Here the articular facets of the scaphoid, trapezium, and trapezoid are opposed to one another but do not meet. If it were not that this transverse groove is interrupted in the region of the os magnum, the carpus would appear when viewed from behind as if divided into an upper and a lower part. Beyond the os magnum the groove is continued

to the inner border of the carpus by a deep serpentine gap, which intervenes between the pyramidal and unciform bones, and which at the margin of the carpus is continued right through to the anterior surface. The head of the os magnum is closely applied to the scaphoid and lunar above, but at its radial side it is separated by an interval of 5 mm. from the scaphoid. A narrow strip of articular cartilage is left exposed on the head of the os magnum towards its radial side. The quadrilateral space between the lunar, unciform, os magnum, and pyramidal bones, seen from in front, is still better marked posteriorly; its increased size is mainly due to the sloping surface of the posterior of the unciform involved. This permits of the movement of dorsiflexion.

At the radio-carpal joint the wide interval between the ulna and pyramidal bones, described in the anterior view, is here also well seen. A considerable portion of the articular cartilage covering the lunar and scaphoid bones on their upper aspect is visible below the radius.

The articular facets exposed on removal of the first row of bones may be considered as forming one complex surface. This may be divided into three parts:—(1) An ulnar part formed by unciform and os magnum, and ending at the radial line on the head of the latter (which is its highest point in this position of the wrist). This surface is convex above, and, winding down the unciform, it becomes concave and ends anteriorly at the base of the hook. This area may meet three bones—viz., the scaphoid, lunar, and pyramidal; in extension of the wrist, however, only the latter two bones articulate with it. (2) An area on the outer aspect of the head of the os magnum convex, and almost in more or less complete contact with the scaphoid. (3) An area composed of the superior surfaces of the trapezium and trapezoid, directed upwards, slightly concave and more or less in contact with the scaphoid. The first portion acts as a screw and inclined plane, and the second and third portions as levers, as will be noticed later on.

Right Wrist in Slight Ulnar Flexion.

In the position of "the hand at rest," about 10° of ulnar flexion is present. The positions of the various bones differ only slightly from what may be found in the straight position. Such differences as are found become more marked in complete ulnar flexion.

Seen from the Front (fig. 3).—The tubercle of the scaphoid is not quite so prominent; a slight amount of dorsiflexion of the bone has taken place. For the same reason the ulnar extremity of the anterior surface is on a more anterior plane. The lunar bone is also dorsiflexed, and covers more of the articular surface of the head of the os magnum, leaving only 1.5 mm.

exposed (compare figs. 1 and 3). The pyramidal bone is also dorsiflexed, its long axis is less oblique, and it occupies slightly more anterior plane. The upper end of the unciform touches the lunar, and the quadrilateral space is reduced to a fissure. There is less of the articular surface of the unciform out of gear.

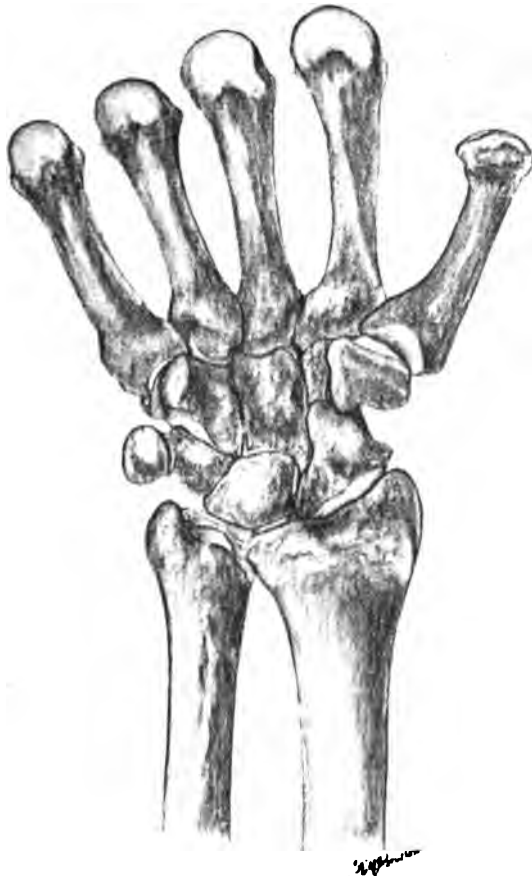


FIG. 3.—Right wrist in slight ulnar flexion ("position of rest"), seen from the front.



FIG. 4.—Right wrist in slight ulnar flexion, seen from behind.

Seen from Behind (fig. 4).—The dorsiflexion of the first row of bones is clearly seen, and none of the articular cartilage of the lunar is visible. The corresponding change in the scaphoid is not quite so marked. The separation of the scaphoid from the trapezoid and trapezium is more marked than in the straight position. The lunar still articulates with the part of

the head of the os magnum situated between the two ridges. The head of the os magnum shows relatively a large amount of articular cartilage (compare figs. 2 and 4); this change is to be associated with dorsiflexion of the scaphoid bone. The unciform and lunar fail to meet posteriorly, but approach one another. The unciform and pyramidal show the serpentine gap described earlier; but it is of less length, as the bones come together at the ulnar side.

Right Wrist in Ulnar Flexion.

It will be at once apparent, on contrasting figs. 5 and 6 with 1 and 2, that but slight lateral movement has taken place at the radio-carpal joint. Lateral movement in ulnar flexion mainly takes place at the mid-carpal joint, but a comparison of the figures brings out the fact that ulnar flexion is associated with dorsiflexion of the first row of carpal bones.

Seen from the Front (fig. 5).—The tubercle of the scaphoid is far less prominent, and it lies much more externally. The entire bone has rotated round an axis which extends from the attachment of the external lateral ligament through the centre of the head of the os magnum.

Twice as much of the upper articular cartilage of the scaphoid may be seen from the front, and the ulnar extremity of its anterior surface has come well forward. Externally, only 3 mm. of its articular cartilage is out of contact with the radius; this articulates with the external lateral ligament of the wrist. The radial edge of the lunar has travelled as far as the ridge on the inferior surface of the radius, and the superior scapho-lunar ligament has crossed over on to the facet for the scaphoid. The lunar is never found to cross over to the radial side of the ridge. The amount of movement from side to side of the first row of bones appears accurately to correspond to the length of this ligament—namely, 3 mm. Owing to the dorsiflexion of the bones of the first row, a large amount of the superior articular surfaces of the lunar and scaphoid show in front (compare figs. 1 and 5). The pyramidal bone, as far as its superior cartilage-covered surface is concerned, is adapted to the triangular fibro-cartilage, its anterior surface looks directly forwards, and its longitudinal axis lies almost in a transverse plane.

At the mid-carpal joint we note that there is more complete adaptation of the bones on the ulnar, and less complete on the radial, side. The unciform and pyramidal bones are in apposition; but their articular facets do not quite correspond, as the former lies in a more posterior plane than the latter so that a narrow strip of cartilage 1 mm. in breadth is exposed (not seen in figure). The unciform has moved as far backwards and upwards as possible, and is screwed home. (The pisiform is not shown in the figure.)

The upper end of the unciform articulates with the lunar, and has rolled on the narrow concave facet of the latter. All the cartilage of the head of the os magnum is covered anteriorly; the concave facet of the scaphoid has crossed the radial ridge on the head of the os magnum for a distance of 4 mm., and articulates with part of the surface formerly in contact with

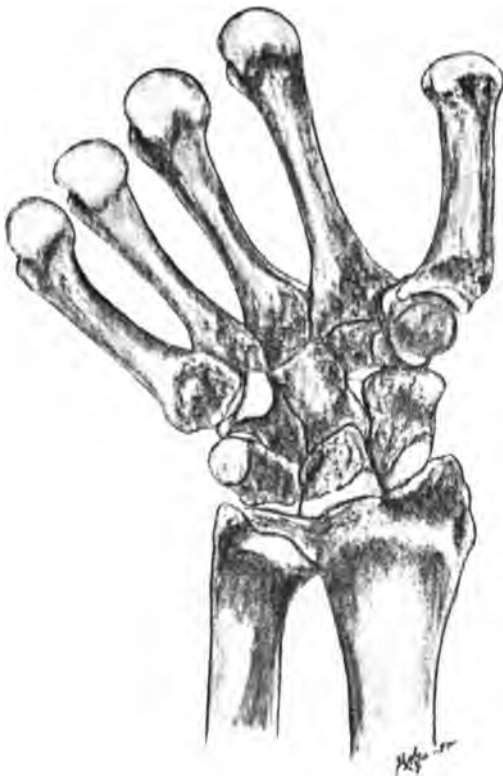


FIG. 5.—Right wrist in ulnar flexion, seen from the front. (The pisiform bone is not present.)



FIG. 6.—Right wrist in ulnar flexion, seen from behind.

the lunar. Distally, however, a portion of the radial side of the head of the os magnum is free, owing to the dorsiflexion of the scaphoid (see fig. 5).

The anterior half of the superior articular surfaces of the trapezium and trapezoid are out of play, owing to the backward movement of the lower end of the scaphoid. The change in the position of the axis of the os magnum is strikingly shown by a comparison of figs. 1 and 5. A movement of the unciform on the os magnum was found to take place in ulnar flexion, which is not easily shown in a drawing. The upper end of

the unciform projects forwards 1 mm. and exhibits a corresponding amount of articular cartilage in front of the os magnum; this is evidently caused by the lower end of the unciform being pushed well backwards, and appears to be the only marked example of movement between the bones of the second row.

Seen from Behind (fig. 6).—A most marked change has taken place at the mid-carpal joint, and the large amount of articular cartilage displayed is most striking. Almost all the inferior surface of the scaphoid is free, but at the extreme distal end it articulates with the trapezium and trapezoid. The head of the os magnum has moved well out of the concave facet of the scaphoid, and the relationship (mentioned above) of the scaphoid to the radial ridge on the head is exhibited. A large area of the head of the os magnum is uncovered by the lunar; the upper end of the unciform touches the lunar. The pyramidal and unciform at the ulnar side of the wrist are lightly applied; the gap seen in the straight position is here closed, but it remains open radially to allow of dorsiflexion. Rather less of the articular surface of the scaphoid is seen below the radius than in the *dorsum* of last specimen. The lunar is inconspicuous and tends to be hidden under the radius, and none of its articular cartilage shows. A strip of articular cartilage on the ulnar side of the os magnum, 1 mm. broad, is exposed posteriorly to the unciform; this corresponds with what has been described on the anterior aspect in the preceding paragraph.

SUMMARY OF IMPORTANT CHANGES IN ULNAR FLEXION.

1. Only slight lateral movement occurs at the radio-carpal joint, and the lunar does not encroach on the scaphoid area of the radius.
2. Dorsal flexion of the first, and volar flexion of the second row of bones (Fick).
3. Screw movement of the unciform on the pyramidal.
4. The unciform meets the lunar for the first time in slight ulnar flexion.
5. Exposure anteriorly of articular surfaces of the os magnum, trapezoid, and trapezium, due to dorsiflexion of the scaphoid.
6. Rotatory movement between the os magnum and unciform.
7. Dorsally, a large amount of the inferior articular facets of the scaphoid is out of play.
8. No articular surface of the lunar is exposed posteriorly.
9. Partial closure of the gap between the unciform and pyramidal posteriorly.

Explanation of some of the changes :—

1. The tension of the lateral ligaments limits the lateral movement.
2. Dorsiflexion of the scaphoid is the resultant of two forces acting from different points—viz., tension of the external lateral ligament from above, and the pull of the ligaments joining the trapezium to the tubercle of the scaphoid which are strained in ulnar flexion. The superior part coming forward brings the lunar with it. The pressure of that part of the head of the os magnum, which articulates with the scaphoid, assists by rendering the ligaments more tense. The change in the axis of the scaphoid is necessary because the outer border of the carpus requires to be lengthened in ulnar flexion.
3. Inspection of the opposing articular surfaces of the unciform and pyramidal will explain this movement. The articular facet on the unciform shows a groove starting from below, winding in a spiral fashion and terminating posteriorly; it seems as if the bone had been caught at the apex and twisted. The pyramidal opposes to this a surface divided into two parts—an outer and anterior part concave and triangular, and a posterior convex from before backwards and slightly concave from side to side. If the bones are articulated together and moved on one another, *e.g.* from ulnar to radial side, the long axis of the pyramidal not only becomes most oblique, but the upper part of the anterior surface comes more forward—dorsiflexion—and the whole pyramidal bone is carried forward. The unciform behaves like a screw, an inclined plane, and a lever, and the effect occurs when the anterior edges only of the opposing bones are in contact. The movement of dorsiflexion is communicated to the lunar, and the first row pressing on the second causes volar flexion of the latter so that "*the hand remains in one plane*" (Fick).
4. When the apex of the unciform touches the lunar, further ulnar flexion is allowed by the pyramidal being pushed upwards and forwards, the ulnar border being thus shortened.

Left Wrist in Radial Flexion.

Seen from the Front.—The tubercle of the scaphoid has come markedly forward, and is the most anterior projecting point of the carpus; it has also moved upward and to the ulnar side, and lies to the ulnar side of the ridge on the trapezium.¹ The upper part of the scaphoid is distinctly on a posterior plane.

¹ It would appear that the tendon of the flexor carpi radialis, as it passes along the ulnar side of the tubercle as round a pivot, would push the tubercle outwards and so cause ulnar flexion. It cannot, therefore, be regarded as a radial flexor.

Inspection of the mid-carpal joint shows that striking changes have taken place, and these are rendered more apparent by comparing figs. 1 and 7. The anterior portion of the inferior articular facets of the scaphoid are no longer in contact with the trapezium and trapezoid, and a strip of articular cartilage on the scaphoid, 4 mm. broad, is exposed. The scaphoid has separated from the os magnum at its lower part, and is now in front of the latter.

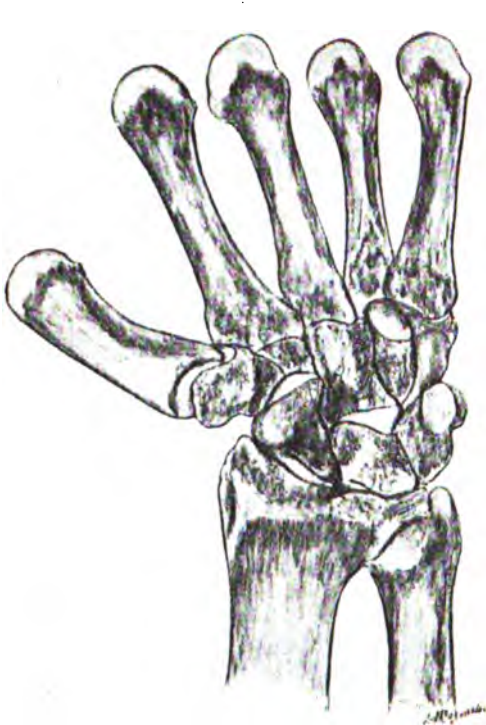


FIG. 7.—Left wrist in radial flexion, seen from the front.
(The pisiform bone is not present.)

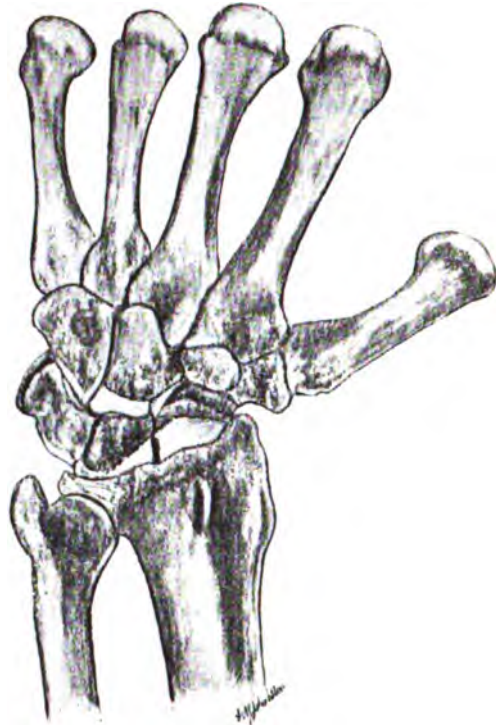


FIG. 8.—Left wrist in radial ulnar flexion,
seen from behind.

The concave facet of the scaphoid is in contact with the head of the os magnum only as far as a point 3 mm. from the radial ridge on the head. The lunar covers the area on the head of the os magnum which in the straight position of the wrist-joint is in contact with the scaphoid, and hence cannot reach the upper end of the unciform. The pyramidal is seen to articulate with the os magnum over an area 5 mm. in extent; its inferior articular facet, which in extension and ulnar flexion of the wrist-joint is in contact with the unciform only, has crossed the ulnar of the two ridges on

the head of the os magnum, and assists in forming the concave socket for the head; further, the rounded upper end of the unciform which in ulnar flexion reaches the lunar, is in radial flexion articulated with the under aspect of the pyramidal bone. But the unciform, notwithstanding this, articulates to a slight extent only with the pyramidal, because the lower two-thirds of the supero-internal surface is free, and appears at the inner margin of the wrist. The unciform as a whole lies on a somewhat anterior plane to the pyramidal; as is to be expected, the axis of the os magnum is strikingly altered.

In contrast to what occurs at the mid-carpal joint, at the radio-carpal joint but little articular cartilage is exposed. The upper articular surface of the scaphoid has travelled as far as the antero-posterior ridge on the under aspect of the radius, and but little of the articular cartilage can be seen from the front. The upper surface of the lunar is in contact for the most part with the triangular fibro-cartilage, and practically none of its articular surface is exposed in front. Almost all of the superior articular facet of the pyramidal is in contact with the internal lateral ligament.

Seen from Behind (fig. 8).—Here, as in the view from the front, the articulation of the pyramidal with the head of the os magnum and that of the upper edge of the unciform with the pyramidal is plainly shown. The unciform and pyramidal are now closely applied, only sufficient gap is left to permit of dorsiflexion.

Considerably less of the articular surface of the head of the os magnum is exposed than in the position of ulnar flexion (compare figs. 6 and 8), and no articular cartilage is exposed between the scaphoid above and the trapezium and trapezoid below. The scaphoid as a whole has become tilted in such a manner that its lower end has passed forwards and its upper end backward. The outer end of the dorsal groove, mentioned on page 113 as separating the distal from the proximal row of the carpus, is in radial flexion entirely bounded by non-articular surfaces.

At the radio-carpal joint a large amount of the articular surface of the scaphoid and lunar bones is exposed, owing to the volar flexion of the first row.

SUMMARY OF IMPORTANT CHANGES IN RADIAL FLEXION.

1. Slight lateral movement at radio-carpal joint.
2. Volar flexion of the bones of the first row and dorsal flexion of those of the second (Fick).
3. The large amount of the articular surface of the unciform on its supero-internal aspect out of gear.

4. Closure of gap between scaphoid and bones of distal row posteriorly, and exposure of the inferior articular surface of the scaphoid anteriorly.
5. No articulation between the lunar and the unciform.
6. Articulation of the upper end of the unciform and part of the head of the os magnum with the pyramidal.
7. Almost complete obliteration of the gap between the unciform and pyramidal posteriorly.
8. Owing to volar flexion of the first row of bones, a considerable amount of the articular cartilage of the scaphoid and lunar bones is exposed posteriorly below the radius.
9. Altered relationships of the scaphoid and lunar to the head of the os magnum.

Explanation of some of the changes:—

2. This change is caused by the lever action of the trapezium and trapezoid throwing the lower end of the scaphoid forwards, and also by the unscrewing of the unciform from the pyramidal. It is impossible for the radial border of the wrist to be shortened by the scaphoid moving ulnarwards on the radius, and the only way possible is to cause the scaphoid to volar-flex so that the articular surface which could not be accommodated under the radius may be exposed posteriorly. The second row has dorsi-flexed for the same reason that it is volar-flexed in ulnar flexion.

3. The effect of this is to lengthen the ulnar border of the wrist.

In the second part of this communication I propose to give an account of the remaining preparation enumerated at the beginning of this paper.

NOTES ON PREDYNASTIC EGYPTIAN TIBIÆ. By DOUGLAS E. DERRY, M.B., Ch.B. Edin., *Assistant Professor of Anatomy, Egyptian Government School of Medicine, Cairo.*

THE following notes have been made as the result of the examination of a series of between four and five hundred predynastic Egyptian tibiæ. A large amount of work has already been done by various observers on the tibia, and particularly in relation to those peculiarities which are seen to greatest advantage in the bones of Eastern and other peoples and in prehistoric bones. It is not, therefore, an easy matter to add much that is new to the knowledge already gained, but it is hoped that one or two points emphasised in the present paper may aid in simplifying the solution of some of the problems which still remain open.

The peculiarities referred to above, and which occur with considerable frequency in the bones under consideration, are platycnemia or flattening of the tibial shaft, retroversion of the head of the bone with or without backward curvature of the shaft, convexity of the external condylar facet, and the presence of additional facets at the lower extremity for articulation with the neck of the astragalus. The condition first mentioned, that of platycnemia, is the one particularly alluded to in these notes.

In order that the significance of the remarks to be made may be thoroughly understood, it will be necessary, in the first place, to recall what has already been done in this direction by other observers, and in particular by Manouvrier. This author considered the platycnemic condition to be due to over-action of the tibialis posticus muscle, with a consequent development of its area of attachment to the tibia, the usual action of the muscle being reversed, so that it takes its origin from below and acts on the tibia. This theory, applied as it was by Manouvrier to the inhabitants of mountainous districts, has been shown by Charles to be inapplicable to natives of the Punjab; and Duckworth also points this out in connection with the prehistoric tibiæ from Egypt in the Cambridge Museum. Professor Arthur Thomson, however, agreed with Manouvrier as to the influence of the tibialis posticus in producing platycnemia, as also did Charles, though the latter believed that it was the action of the muscle in its connection with the squatting attitude which was productive of the flattening. Poirier, in his

"*Traité d'Anatomie Humaine, Ostéologie*, tome i. p. 244, follows Manouvrier absolutely.

On the other hand, Manouvrier himself has shown that both platycnemic and non-platycnemic bones may occur in any population; and recently Mr Macrae Aitken, in "A Note on the Variations of the Tibia and Astragalus," published in the *Journal of Anatomy and Physiology*, vol. xxxix., p. 489, has demonstrated the occurrence of all the peculiarities generally attributed to Eastern or prehistoric bones in normal European tibiae. He finds that the bones may be divided into two different types, (1) Oriental, and (2) European, the former being "shorter and much slighter in build than the European; and also that the impressions for the attachment of muscles and the groove for the tendon of the tibialis posticus were less distinct in bones of the former type." In the same paper he says:—"The usual statement that platycnemia is associated with over-development of the tibialis posticus muscle, was not borne out by the appearance of the bones examined; those with the lowest platycnemic index were slender and smooth, and showed least evidence of attachments of powerful muscles, while the large, strongly marked bones of the European type had the highest index."

It is evident from this that some more satisfactory explanation of the associated conditions is required, and accordingly Mr Macrae Aitken believes that platycnemia is due to "altered lines of transmission of the body weight," brought about by retroversion of the head of the tibia, so throwing an antero-posterior strain on the bone, which nature meets by increased growth in that diameter. The requisite retroversion of the head which this theory demands is produced, presumably, in the European by the persistence of a uterine condition, and in true Oriental bones by the adoption of the squatting attitude.

Before discussing the different points for and against the theories mentioned, attention must be drawn to certain well-marked characteristics of the bones as a whole, which appear to have some bearing on the platycnemic condition. Chief of these is the posterior vertical line which descends from the oblique line, and in bones of the European type separates the surfaces of origin of the tibialis posticus and flexor longus digitorum muscles. This line varies considerably in length and prominence in different tibiae, and in most cases gradually approaches the interosseous line; in others it is continued straight down, and in these latter there would, therefore, be a greater area of bone at the disposal of the tibialis posticus muscle than would be the case if the vertical line joined the interosseous ridge high up. In a number of the bones under discussion, however, this line appears to become remarkably prominent, so much so that it has been described (by Duckworth) as a "keel or flange," which projects backwards, changing the

posterior surface of the tibia, in some instances, into a rounded border. This condition is usually associated with pronounced platynemia, and it may here be mentioned that bones showing this character to the greatest advantage were frequently much curved in a backward direction. Another characteristic of a large number of these bones is the change in position of the interosseous ridge. This is not merely an apparent change due to an increase of the area of bone behind the ridge, as compared with that in front, though this is what might be expected from an hypertrophied tibialis posticus muscle. It is an actual alteration in position of the line, so that if it were continued upwards, it would in many cases pass altogether in front of the tuberosity instead of terminating just in front of the fibular articular facet. The area of origin of tibialis posticus is thus increased, while that of tibialis anticus is proportionately diminished. In a normal European bone as much as 60 per cent. of the whole outer surface of bone, measured between anterior and posterior borders, may be in front of the interosseous line; while in many cases amongst the Egyptian bones fully 60 per cent., and in some as much as 63 per cent., is behind the ridge. While this arrangement seems to be to some extent related to the platynemic condition, it is by no means exclusively confined to this type of tibia, some of the best-marked cases of this interosseous displacement being seen in bones with higher indices. In the *Journal of Anatomy and Physiology*, April 1906, Mr J. Ernest Frazer, in a paper entitled "Some Minor Markings on Bones," draws attention to this very point, and it would be interesting to know whether he finds any constant relationship between the position of the line and flattening of the tibia. Lastly, the head of the bone appears large in proportion to the size of the shaft, and the area for insertion of popliteus muscle appears to be considerably smaller than in European bones.

There are certain objections to the theory propounded by Manouvrier as to the cause of platynemia. Everything is made to depend on hypertrophy of tibialis posticus muscle, brought about by over-action in a particular form of exercise and in mountainous countries. As already mentioned, however, this has been shown to be of no account in those races living in flat countries. Some other cause for such over-action of the muscle must therefore be found, and this Charles sees in the constant squatting of those people who show the condition to greatest advantage.

Without doubt the area of bone concerned with the attachment of the tibialis posticus muscle is often affected, and if every platynemic bone presented the same modifications in this area, no difficulty would be experienced in accepting the theory. But this is by no means the case. While many bones show an undoubted increase in the space allotted to the muscle named, there are others with very distinct bony landmarks showing

nothing abnormal in their position or relative size, but associated with marked platycnemia. Again, bones with the same changes in area of origin of tibialis posticus muscle are frequently not at all flattened. It would seem, therefore, that no constant relation exists between the two conditions. Further, it is found on measurement that if a series of platycnemic bones is compared with a set of European tibiae, it is not in the sagittal diameter, but in the transverse, that the chief differences are observed. In other words, the supposed hypertrophy of tibialis posticus muscle has not so much increased the antero-posterior diameter, but rather has produced marked reduction in the transverse. This is quite at variance with the action hitherto ascribed to this muscle of causing expansion of the bone antero-posteriorly. In this connection Duckworth says: "The area of tibial attachment of the M. tibialis posticus is drawn backwards in the form of a keel or flange, which thus increases the sagittal diameter of the tibial shaft, the transverse diameter experiencing comparatively little change" (*Morphology and Anthropology*, chap. xiii., p. 322).

The measurements of European bones have been taken from Professor Arthur Thomson's paper in the *Journal of Anatomy and Physiology*, vol. xxiii. p. 616, on "The Influence of Posture on the Form of the Articular Surfaces of the Tibia and Astragalus." The actual average measurements are for twenty European tibiae, sagittal diameter 33.5, transverse 24.7. For twenty-seven Egyptian bones chosen as typical examples of platycnemia with a well-developed ridge, the same measurements are for the antero-posterior diameter 34.9, and for the transverse 20.9. The measurements here given are on platycnemic bones, which should therefore give, according to Manouvrier's theory, a much larger sagittal measurement than European tibiae. Finally, in some of the best-marked cases of flattening, the part of the bone affected extends beyond the sphere of action of the tibialis posticus muscle, which has generally been supposed to exercise its flattening action at or about the level of the nutrient foramen. In the cases referred to the most attenuated part of the bone is often the middle or junction of middle and lower thirds of the shaft.

As regards the theory of Mr Macrae Aitken that platycnemia is due to increased growth antero-posteriorly to meet a strain in that direction from a retroverted head, it may be stated that, while it is true that some of the most platycnemic bones are also very bent, yet this again is not constant. Many of the bones which, from their general size and conformation, might be classed as European, are markedly bent, while on the other hand extremes of flattening are found with perfectly straight tibiae. Further, as has already been shown, the flattening is not so much due to increase in the antero-posterior diameter as to reduction in the transverse.

No one examining a similar large series of bones as regards the particular condition of platynemia could help being struck with the fact that the tibiæ reveal at least two different forms of flattening. In the one case the greatest antero-posterior diameter is, from crest of tibia to the rounded posterior border, generally constituted by an overgrowth of the vertical line above referred to. In these bones the posterior surface has practically disappeared, and what remains of it slopes gradually away on either side of the vertical line, marking the insertions of the two muscles flexor longus digitorum and tibialis posticus. But there is a second type less frequent, but still quite distinct, in which the posterior vertical line has remained small, and now the greatest sagittal diameter is between anterior border and what in a normal bone would be the internal border. Such bones provide some of the best-marked cases of flattening, and they have the further interest that they supply additional evidence against the theory of platynemia being due to over-action of tibialis posticus. Mr Ernest Warren, in his paper entitled "An Investigation on the Variability of the Human Skeleton," which refers especially to bones of the same race as those at present under discussion, says:—"In the platynemia of the gorilla both the tibialis posticus and flexor longus digitorum are inserted on the outer side of the expansion, while in the platynemia of man the latter muscle comes to be inserted on the inner surface, being pushed round, so to speak, by the great extension of the area of attachment of the tibialis posticus." In the type of tibia last referred to, much the same condition is found as that said to be present in the gorilla. For if the internal border, or a border corresponding very closely to it, is the most projecting point posteriorly, it follows that both tibialis posticus and flexor longus digitorum must be inserted on the outer surface of the bone; and there can be in consequence no question of an hypertrophied tibialis posticus pushing the flexor longus digitorum round to the inner side; nor can the projection be due at any rate to tibialis posticus alone, as *might* possibly be the case in the form of tibia first mentioned, whose platynemia appears to be largely constituted by a projecting vertical line.

More than one author writing on this subject refers to the antero-posterior diameter as being increased *behind* the interosseous ridge, following the original statement of Manouvrier; but, as already shown, there is very little increase in the sagittal diameter, the marked flattening being brought about by reduction in the transverse measurement. It may justly be asked how such a statement as that of Manouvrier has been made. The writer believes that it is chiefly due to the fact before referred to, that in such a large number of the bones the interosseous ridge is altered in position, so that instead of running upwards to the under aspect of the

external tuberosity close to the fibular articular facet, it travels gradually forward, causing an ever-increasing area of bone behind its course, with a corresponding decrease in front. And this error is the more likely to be perpetuated seeing that a large number of non-platynemic bones have the line in its normal position, while the majority of platynemic tibiae show more or less alteration in their interosseous ridges. The appearance is therefore that of an increased area for tibialis posticus muscle, and the natural deduction is to regard the increase as due to the muscle. The point which the writer wishes to bring out is, that if the interosseous line held its normal position there would be little appearance of any increase posteriorly. This does not mean, however, that there may not be such an increase; for, as has already been shown, there may be projections due either to the vertical line or to the internal border; but in such cases the area for tibialis posticus is not markedly increased.

The writer has before him two bones whose antero-posterior diameters are precisely the same; the bones are also of the same length and general size, yet the one has an index of 58.6 and the other 65.5. It is obvious that the difference here must be in the transverse measurement; and this is the case, the first-mentioned bone giving 17 and the other 19 in the transverse diameter. Further, the interosseous line takes a different course in the two, giving in the more platynemic bone the appearance of a considerable increase behind its course, whereas it has been seen that both bones measure the same sagittally, and the difference is merely due to an alteration in the position of the line itself.

A very careful comparison of two bones, platynemic and non-platynemic, brings out some significant facts. Looked at from in front, the former is obviously much flattened; and this in front of as well as behind the interosseous line, and in almost the whole extent of the shaft. The difference is first noticeable immediately below the tuberosities, where the bone shelves away very quickly, so that in many of these tibiae the head appears to be abnormally large. This attenuation is visible on both sides of the anterior border, but it is most marked on the outer side, when the bone is viewed from before. If the bones are now turned round and examined posteriorly, the differences are very striking. The whole popliteal surface is markedly reduced, particularly in the transverse diameter, falling rapidly away on the inner side and causing the inner tuberosity to appear to project inwards abnormally. On the outer side of the popliteal line, still looking at the bone from the posterior aspect, there is again the same falling in of the bone, the area for tibialis posticus becoming practically a part of the outer surface of the tibia instead of being situated, as in bones of European type, partly on the posterior

surface. The appearance in an extreme case is as if the bone had been divided vertically, all that part to the outer side of the popliteal line being removed, and leaving in consequence a flat external surface. The point to be emphasised is the extraordinary flattening of this part of the bone at the expense of the popliteal surface. Continuing the comparison, the flattening which is so marked immediately below the head continues in the same degree downwards, reaching its greatest attenuation in some bones about the middle of the shaft, in others even lower, and reducing in consequence the posterior surface to little more than a rounded border.

Turning now to the outer surface, the most striking contrast between the two types of tibiæ is the position of the interosseous line already referred to, and the flattening of the whole area. In some of the bones it will be noticed that the interosseous line appears to keep a more or less central position throughout its course along the shaft; and in such cases it does not form, as in European bones, the outer border of a posterior surface. This latter is in fact in such bones either non-existent or so sloped outwardly that it practically becomes a part of the outer surface.

Since it is around the portion of the bone giving origin to *tibialis posticus* that the whole argument for platycnemia centres, some further attention must be directed to the varying conditions observed. If a series of non-platycnemic bones be examined—and for the purposes of the present paper all bones giving an index of 70 or over may be so classed—it will be found that great differences exist in the size of the area for attachment of *tibialis posticus* muscle. In the most typical bones, or those which follow most closely the arrangement usually described in text-books, the area is small; and this too in some cases of large, well-marked tibiæ; in other bones it is large, and oftentimes much larger than the similar area on a highly platycnemic bone. Its extent is largely governed by the position of the interosseous line, which, however, is not so often displaced forwards as is the case in platycnemic bones. But there is another difference between the platycnemic and non-platycnemic bones, and that is the appearance already referred to of a marked falling-in of the outer surface in the neighbourhood of *tibialis posticus* attachment. There can be no doubt that it is the reduction in breadth, by whatever cause effected, in this region, that gives rise to the disproportion between sagittal and transverse measurements. There is undoubtedly a backward projection of the vertical line, but this is invariably associated with reduction in the transverse diameter. As a result the border formed by interosseous line between external and posterior surfaces is smoothed out, and that part of the posterior surface giving origin to *tibialis posticus* becomes a part of the external surface. It is not easy to understand how hypertrophy of a muscle could cause what practically

amounts to atrophy of the bone; nor why the hypertrophied muscle of the platycnemic bone should require *less space*, as in many instances, than the same muscle of a normal bone.

Such facts seem to make it clear that the theory of platycnemia commonly accepted requires modification. It is not without significance that over 65 per cent. of the pairs of bones measured gave a smaller index for the left than for the right bone. Mr Ernest Warren has also shown that of the male tibia 61.4 per cent. have the left bone *longer* than the right, and of the female 62 per cent. This of course might be taken as additional evidence in favour of Manouvrier's theory of excessive muscular action, seeing that the left lower extremity preponderates over the right in certain particulars; but enough has been said to show that some other influence than muscular action, at least alone, must be responsible for the extreme attenuation illustrated by many of the tibiae.

A DESCRIPTION OF THE PERITONEAL CAVITY, FOUNDED ON
CLINICAL AND PATHOLOGICAL INVESTIGATIONS. By
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late Demonstrator of Anatomy, St Mary's Hospital.*

RECENT observations on the pathological processes which take place in the peritoneal cavity have directed our attention to the parts most frequently affected. These observations suggest a modification in the method of describing the cavity—or rather potential cavity—of the peritoneum. It will readily be admitted that the student can only arrive at a good understanding of the anatomy of the peritoneum by studying its morphology and its relation to the various viscera and the enclosing abdominal wall. But we think it desirable that more detailed attention should be given to the peritoneal cavity itself, having regard to the importance of this serous space clinically.¹ We therefore suggest the following description, based on clinical and pathological as well as anatomical grounds, as one likely to be of value to both the student and the practitioner.

The peritoneal cavity is described as consisting of two great parts—the greater and lesser sacs. The description of the lesser sac as it stands is sufficient for practical purposes. The lesser sac, with its walls projecting downwards and forwards, divides the greater sac into two main divisions. This dividing partition is composed in large part of the omentum, and Mickulicz has suggested as appropriate names for the two parts the supra-omental and infra-omental divisions (fig. 1). It is not necessary for us to describe the relations of the divisions. They are sufficiently obvious. It will readily be recognised that these two divisions communicate at the free border of the great omentum (fig. 1). They also communicate laterally: *in the right flank* to the outer side of the commencement of the transverse colon internal to the lower border of the liver; and since the lower border of the right lobe of the liver projects into the infra-omental

¹ One of us, nearly two years ago, demonstrated some of the features of the peritoneal cavity that seemed important from a practical standpoint to the members of the Polyclinic and to a scientific society at a London hospital.

division, there is an additional communication outside that border between it and the abdominal wall: *in the left flank* they communicate to the outer side of the termination of the transverse colon in front of the phrenico-colic ligament (fig. 2).

The supra-omental division consists of two lateral parts separated by the falciform and round ligaments. We name these the right and left supra-omental regions. The communication between these two regions is bounded in front by the liver, the round ligament, and the abdominal wall;

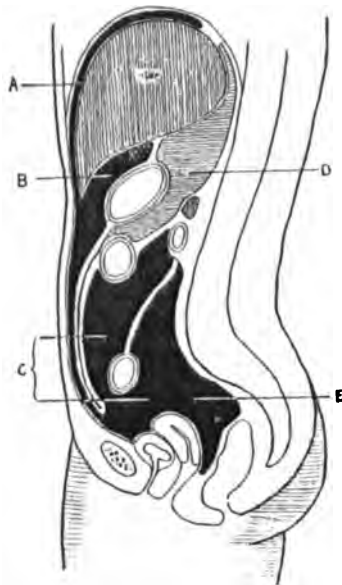


FIG. 1.—Diagrammatic sagittal section of abdominal cavity, showing divisions and pouches.

A, subphrenic pouch; B, subhepatic pouch; C, infra-omental division; D, lesser sac; E, pelvic recess.

behind by the lesser omentum, the stomach, and the greater omentum (fig. 1).

In connection with these two regions are certain recesses which possess great practical importance (figs. 1 and 2). From the right supra-omental region there is a recess passing upwards and backwards between the liver and the diaphragm—the right subphrenic pouch; and another recess passing upwards and backwards beneath the liver—the right subhepatic pouch (a space described by Rutherford Morison and others). Into this latter pouch the lesser sac opens through the foramen of Winslow. From the left supra-omental region three recesses may be traced: one in relation

to the spleen—the perisplenic pouch; a second above the liver—the left subphrenic pouch; and a third beneath the liver—the left subhepatic pouch. It may be pointed out here that whilst the two subphrenic pouches have no direct communication with one another, yet the subhepatic pouches communicate freely. In a more complete description we would give the walls of these pouches in detail, especially those of the right subhepatic pouch, which have been described, but, we believe, not quite correctly.

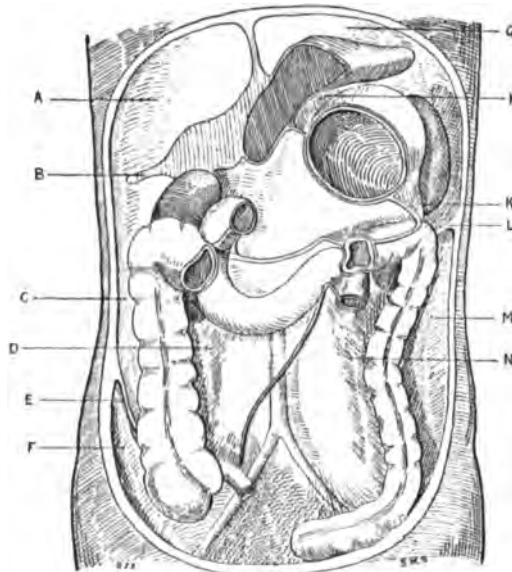


FIG. 2.—Diagram of posterior abdominal wall, showing various depressions.

A, right subphrenic pouch; B, right lateral ligament of liver; C, upper part of right external paracolic groove; D, right internal paracolic groove; E, paracolic peritoneal fold; F, lower part of right external paracolic groove; G, left subphrenic pouch; H, left subhepatic pouch; K, gastro-colic omentum; L, phrenico-colic ligament; M, left external paracolic groove; N, left internal paracolic groove; X, the most posterior point in peritoneal cavity on right side.

The infra-omental division consists, as does the supra-omental, of two parts—the right and left infra-omental regions. This subdivision is brought about by the projection forwards of the vertebral column, the muscles attached thereto, the aorta, the vena cava, and the mesentery (fig 3). These two parts communicate anteriorly in front of the small intestine and behind the transverse meso-colon, the transverse colon, the great omentum, and the abdominal wall. Inferiorly they communicate behind the intestine and below the mesentery through the well-defined pelvic fossa, which may be described as a recess of the infra-omental division.

The anterior parts of the lateral infra-omental regions are irregularly broken up by coils of small intestine and folds of mesentery. The posterior parts form deep vertical gutters on either side. Projecting into each of these gutters in its whole length is the colon—ascending or descending colon as the case may be—forming the internal and external paracolic grooves. The *right external paracolic groove* (figs. 2 and 3) is continuous above with the right subphrenic and subhepatic pouches, whilst below it is continuous with the subcæcal fossa, where the summit of the precipitous wall formed by the psoas muscle is the boundary between the groove and the cavity of the pelvis. This groove is interrupted near the crest of the ilium by a fold of peritoneum passing from the abdominal wall about the

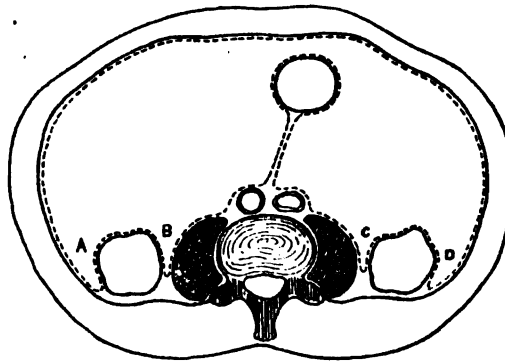


FIG. 3.—Diagrammatic transverse section of abdominal cavity at fourth lumbar vertebra, showing paracolic grooves.

A, left external paracolic groove; B, left internal paracolic groove; C, right internal paracolic groove; D, right external paracolic groove.

level of the iliac crest downwards and inwards to be attached to the lower end of the ascending colon about one inch above the cæcum in the neighbourhood of the postero-external muscular band. The *right internal paracolic groove* (figs. 2 and 3) superiorly reaches the interval between the lower end of the second part of the duodenum and the upper end of the ascending colon; below, it is limited by the termination of the small intestine. The *left external paracolic groove* (figs. 2 and 3) is separated from the left supra-omental region by the phrenico-colic ligament; below, the groove terminates in a space lying behind the movable iliac colon and its mesentery, communicating with the pelvis over the psoas, as on the right side. The *left internal paracolic groove* (figs. 2 and 3) terminates above, in front of the kidney in the inner angle of the splenic flexure; below, it communicates with the pelvic fossa over the common iliac artery, and over the iliac meso-colon which is lying in front of the lower part of the psoas.

In order to complete the description of the peritoneal cavity, it would be necessary to mention the well-recognised fossæ and depressions on the peritoneal aspect of the anterior abdominal wall.

As shown by many observers, including Mickulicz, Morison, Barnard, Moynihan, Wallace, Box, and Kelly, abscesses and other fluid effusions tend to lie in more or less constant relation to certain parts of the posterior abdominal wall and to the more fixed viscera. We wish now to direct attention to a few points in the anatomy of these regions. We have arrived at these conclusions after investigations in twenty hardened and post-mortem room subjects. The body was placed on the back, and fluid was allowed to escape from a tube into the various parts of the peritoneal cavity under consideration. We found that the most convenient fluid for the purpose was a solution of mucilage having zinc oxide in suspension.

Fluid allowed to escape from a tube placed in the various positions assumed by the appendix, tends to gravitate in one of three directions—into the pelvic recess, the external paracolic groove, or the internal paracolic groove. In almost all cases it was only when a large amount of fluid was used that the superior part of the right external paracolic groove formed the site of an accumulation. The reason for this is the almost constant presence of the fold of peritoneum previously described as passing from the abdominal wall to the ascending colon. This paracolic fold is best marked when the cæcum is distended and very mobile, and is best demonstrated before the abdominal wall is completely divided transversely. Arbuthnot Lane has described adhesions on the outer side of the cæcum and colon as causative of certain pathological conditions. We are of opinion that the paracolic fold is so constant as to necessitate its being described as normal, though of course under certain conditions it may become of the pathological importance he states. It is owing to this fold that a large collection of fluid may exist in the iliac fossa and the lower part of the right external paracolic groove without any being found in the upper part of the same groove. If, however, the fluid escapes over the fold, then it at once gravitates to a spot to the outer side of the superior pole of the right kidney, at the level of the eleventh intercostal space, just below the right lateral ligament of the liver. In only one case did fluid accumulate to any extent above the level of the right lateral ligament. Fluid in the right internal paracolic groove passed to the inferior pole of the right kidney and then crossed the colon at the hepatic flexure to the external groove.

By this means we found a series of fossæ—the iliac fossa, the internal and external paracolic grooves. We were also able to demonstrate that the most posterior part of the abdominal cavity on the right side is at the

outer side of the superior pole of the right kidney at the level of the eleventh intercostal space, just below the right lateral ligament of the liver.

On the left side, by similar means, we demonstrated the left internal and external paracolic grooves. The inner groove in the subjects examined was much better marked than the outer, its deepest part being just below the inferior pole of the kidney. A shallow depression on one or other side of the colon immediately below the iliac crest was sometimes present. The most posterior part of the peritoneal cavity on this side was found in all cases to be in relation to the posterior border of the spleen to the outer side of the superior pole of the right kidney, about the level of the eleventh intercostal space.

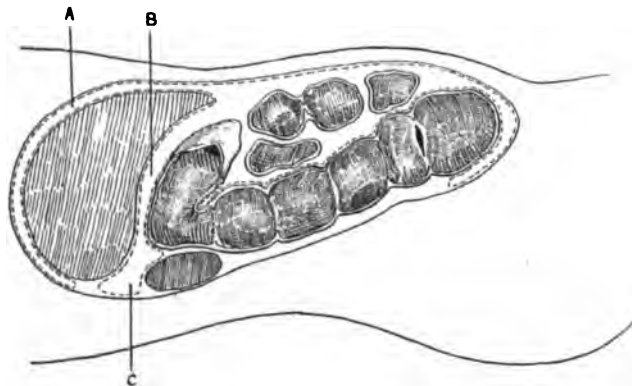


FIG. 4.—Diagrammatic sagittal section at right mid-Poupart plane.
A, right subphrenic pouch; B, right subhepatic pouch; C, most posterior part of peritoneal cavity on right side.

Fluid flowing from the pelvic fossa usually passed out on the left side into the internal paracolic groove, crossing the descending colon near the lower end of the kidney into the external groove and thus to the region of the spleen.

Free fluid on the anterior surface of the stomach flowed either to right or left. If the effusion were near the pyloric end it passed out of the left subhepatic pouch into the right subhepatic pouch; but if to the left of a point about one inch from the mid-line, it made its way into one or all of the recesses of the left supra-omental region.

It seems to us, then, that a detailed account of the peritoneal cavity in relation with the posterior wall of the abdomen is of great practical importance.

THE INTERPRETATION OF THE PRIMARY AND FIRST SECONDARY WAVE IN SPHYGMOGRAPH TRACINGS. By THOMAS LEWIS, D.Sc., M.B., B.S., *University College, London.*

A GREAT deal has been written upon the first two waves of the pulse curve. It is now recognised, in opposition to the views of Sanderson and Mahomed, that the first rise of pressure is due to a pressure wave in the artery. In an article in the *Journal of Anatomy and Physiology*, vol. viii., Galabin attempted to show, by weighting the lever of his instrument, that the two waves could be approximated,¹ and he concluded in consequence that a con-

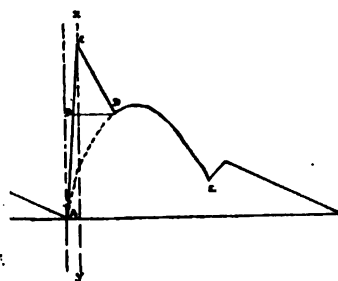


FIG. 1.

siderable amount of the curve is due to "inertia" of the instrument. In his figure, p. 22, his views are set forth. The true wave is considered to be single and rounded, the upstroke less oblique. The peak of the primary wave has no real existence, and the first secondary wave is due to a rebound from the fundamental wave. In a later work (*ibid.* vol. x.) this view was modified, and the *pulsus bisferiens* was taken into consideration. His final conclusion appears to be that sometimes the second curve is actually a representation of a pressure wave in the artery, and that sometimes it is an artifact produced by the instrument. A very similar view is still held by many physiologists. Mackenzie (pp. 19 and 154) is of opinion that the first upstroke is an artifact, and that the tidal wave is the true apex of the curve. No one can doubt that there is a possibility of exaggeration by overriding in tracings representative of pulse pressures, but there has been some difference of opinion as to whether this occurs by virtue of the levers

¹ "Method of Concomitant Variations."

or the tissues compressed. There is more room for difference of opinion when the amount of overriding in a given case is questioned. If the circumstances are considered, it will be apparent that the upstroke (fig. 1) AC cannot be due in its whole length to momentum of levers and tissues, for their inertia at the start would rather tend to decrease the vertical course of this portion of the curve. Moreover, as this inertia is gradually overcome, the line should start with a slight concavity to the left (figs. 2, 5, and 6). As velocity is acquired there is the possibility of overriding taking place, and the actual line traced, as it deviates from the path representative of the true pressures, will be convex to the left. That the whole line is not due to acquired velocity is thus apparent from theoretical considerations. Galabin himself recorded the fact that if a tracing be taken from a "Corrigan" pulse, with the arm elevated, the upstroke often becomes more vertical and yet of smaller amplitude.

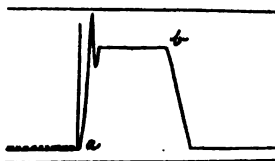


FIG. 2.

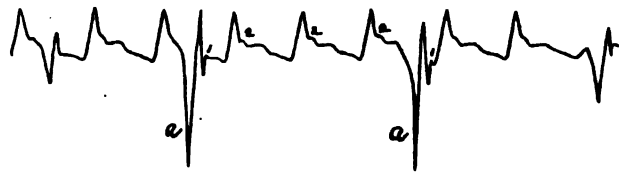


FIG. 3.

Were the whole upstroke an artifact, its obliquity at any point¹ should be proportional to the distance of the line at that point,¹ from the apex of the upstroke. The curves in the upstroke are shown in fig. 2; they are slight, but quite perceptible. The upstroke of the vast majority of tracings from normal pulses showing a predicrotic is straight (*cp.* also the hæmautographs of Landois). Again, given that the movements of the lever travelling over the first curve are due to overriding, the line of descent should be of the same obliquity as the corresponding part of the upstroke. It is true that if the tissues fall faster than the lever, there may be some delay in the downstroke; but, as a matter of fact, it is practically inappreciable. In the tracing given by Mackenzie on p. 154, the downstroke of the lighter pressure tracing is far less vertical than the upstroke, and the tracing itself proves the presence of a true primary wave, though its relations may be somewhat altered. Given a particular pulse in which a predicrotic occurs, there are several methods by which an attempt may be made to prove the truth of the record for the individual. First, the primary wave curve may be compared with "jerk" curves

¹ Considering the tangent.

produced by depressing the pad and suddenly releasing it, the pad being meanwhile off the artery. Such a curve is shown in fig. 2.¹ These curves may be made to interrupt a pulse tracing (fig. 3, in which the paper was travelling slower; α represents the depression of the pad artificially). Both the first peaks and the rebound peaks, marked 1, 1, are far sharper than the corresponding primary wave and predicrotic marked 2, 2. There yet remains the method adopted by Mackenzie, that of increasing or decreasing the pad pressure. Further, if the pad is restrained from falling with the tissues, and this restraint is gradually increased, tracings such as that shown in fig. 4 are obtained. The method is similar to that adopted by Buisson. In such cases the complication of tissue and lever "inertia" is to a large extent avoided. By one or other of these methods the validity of the record, so far as the primary and first secondary waves are concerned, can almost always be proved. At the same time, the possibility of overriding remains in the case of very sudden upstroke (comparing



FIG. 4.

the upstroke in fig. 3 of the primary and jerk wave, the difference in obliquity is obvious). In many such cases the tracings show not a vertical, but a curved upstroke (figs. 5 and 6), parabolic with concavity to the left at the base, similarly parabolic but with convexity to the left at the apex. The amount of overriding is often difficult to estimate in these cases, but there is every reason to believe that it has been exaggerated, and that it will not account for the production of a double-topped pulse, in the great majority of instances. Finally, the tracings given by Galabin are not beyond criticism, either as regards regularity or the method of marking; also the method is complicated by the possibility of an increased pad pressure from the weight attached to the lever. The conclusion seems justified that the pulse wave in the radial artery is a divided wave in the great majority of those cases where the tracing shows it divided, and that those cases only are open to suspicion where the upstroke AC and the downstroke CD are equally inclined to the vertical and are composed of segments of parabolic curves (*cp.* figs. 5, 6, and 7). As to the origin of

¹ The method cannot be adopted with the ordinary sphygmograph; it is necessary to attach a guide for the writing style.

140 Primary and First Secondary Wave in Sphygmograph Tracings

the two waves, and the many views which have been held, little need be said. Curves of intraventricular pressure show the systole divided (*cp.* Marey, Bayliss, and Starling, etc.), as do also curves from the aorta, taken with the most delicate apparatus. There is every reason to believe that



FIG. 5.



FIG. 6.

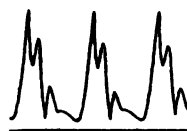


FIG. 7.

they are produced centrally (though they may be enhanced peripherally; *cp.* Galabin). Whether the second wave is produced in the ventricle, as Roy and Adami maintained,¹ or whether it is produced in the aorta, as Marey and many other prominent writers believed, must for the present remain an open question.

¹ Whose statement that the first wave depends on contraction of the papillary muscles has been called in question by the work of Haycraft and Paterson, Fenwick and Overend, and others.

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NOTE ON ACCESSORY CORONARY ARTERIES. By WILLIAM
ST CLAIR SYMMERS, M.B. Aberd., *Musgrave Professor of Pathology,*
Queen's College, Belfast.

I HAVE been repeatedly aware, in performing post-mortem examinations, that the human heart shows one or more small arteries arising from the aorta in the immediate neighbourhood of the origin of one or other of the coronary arteries. The existence of these supplementary arteries has been known since the days of Morgagni, and is briefly mentioned in comprehensive works on anatomy. For example, Quain¹ reads as follows:—"The existence of three arteries is not infrequent, and in a few instances four have been observed, the supplementary vessels being generally small, springing from the aorta near the main coronary trunk, and representing normal branches of the latter which have acquired an independent origin." Poirier² mentions a fact which is strikingly brought out in my own observations, viz., that the supplementary arteries arise more frequently in connection with the right than with the left coronary artery. I may mention, in passing, that the first plate in Richard Quain's famous *Anatomy of the Arteries* (1844) shows that the right coronary is accompanied by a supplemental vessel almost equal in calibre to the main artery. The frequency with which I met these accessory vessels led me to make notes on the point in a hundred successive autopsies, with the following result:—

The vessels are small, being usually from a $\frac{1}{2}$ to 2 mm. in diameter; they arise from the aorta within a few millimetres of the mouth of the principal coronaries (usually the right), run down through the epicardial fat, and are lost over the sternal aspect of the heart, often being easily traceable for 6 or 8 centimetres or more, over the anterior aspect of the right ventricle. In the few instances in which they arise from near the left coronary, they end over the diaphragmatic surface of the heart.

In the hundred hearts here in question, these vessels were as follows:—

There was one right accessory coronary in 26 of the cases.

"	were two	"	"	coronaries	"	9	"	"
"	"	three	"	"	"	2	"	"
"	"	four	"	"	"	1	"	"
"	was one left	"	"	coronary	"	1	"	"

¹ Quain's *Anatomy*, 10th ed. vol. ii. part ii. p. 382.

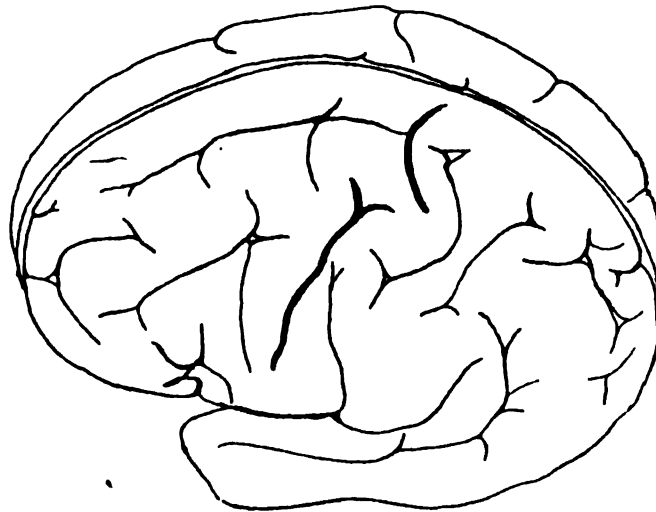
² Poirier, *Traité d'Anatomie humaine*, tome ii. part ii.-iv. p. 664.

There were two left accessory coronaries and two right accessory coronaries in one case.

Thus out of one hundred hearts examined, forty carried these accessory arteries, in the number and disposition above stated; and it will be at once noted how much more frequently the supplementary arteries were present on the right side than on the left—viz., these forty hearts had fifty-nine accessory coronaries, of which fifty-six arose from the aorta near the origin of the right coronary artery.

COMPLETE BILATERAL INTERRUPTION OF THE FISSURE OF
ROLANDO. By DAVID WATERSTON, M.A., M.D., *Lecturer in the
Department of Anatomy, University of Edinburgh.*

COMPLETE interruption of the fissure of Rolando by a bridging gyrus which is on the same level as the rest of the surface of the brain occurs in the fully-developed brain in rare cases. The first case recorded was that described by Wagner (1), and was found by him in the brain of Fuchs.



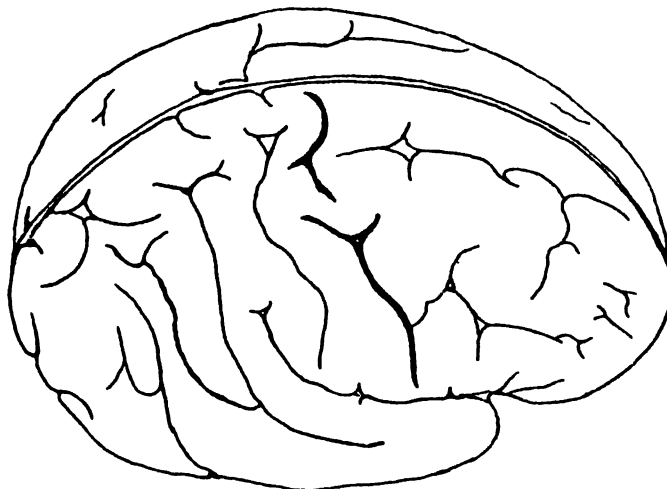
Since then it has been recorded, according to Spitzka, in thirteen additional cases, of which only two showed the condition in both hemispheres (2); and very recently Lattes (3) has described and figured the occurrence of this condition in the left cerebral hemisphere of a female Italian criminal; and Beevor (4) at a recent meeting of the Anatomical Society showed a specimen of this interruption of the fissure in the right hemisphere of an adult male. The recorded cases have hitherto been found in the adult brain, but the condition may apparently be present at birth, as the following instance shows.

The specimen in which I found this condition was the brain of a newly-born and fully-developed female infant.

The antero-posterior length of the brain was 90 mm., while from the

frontal to the occipital pole along the supero-mesial border it measured 145 mm.

Right hemisphere.—The upper end of the fissure of Rolando was situated at a distance of 76 mm. from the orbital and 70 mm. from the occipital pole, and it did not intersect the supero-mesial border of the hemisphere. From that point it ran in a curved manner downwards and forwards for a distance of 21 mm. on the outer surface of the hemisphere. At this point it was interrupted by a convolution which united the ascending frontal and parietal convolutions to one another. This bridging gyrus was on a level with the rest of the surface of the brain, and was 4 mm. in width. Below this level the fissure of Rolando was continued downwards and



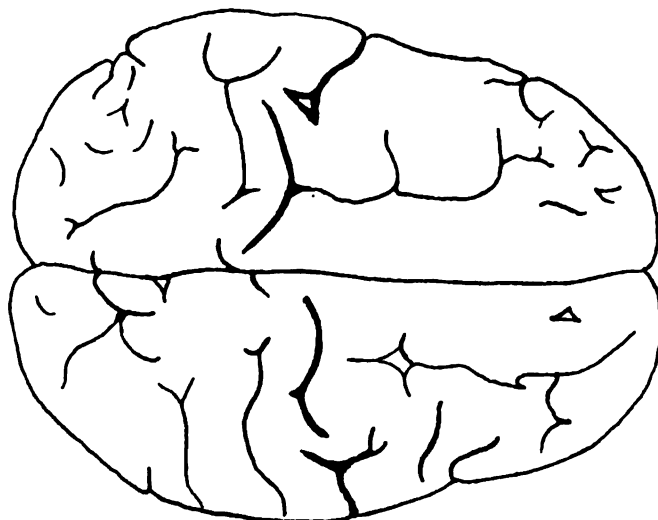
forwards to the posterior horizontal limb of the Sylvian fissure, but it did not intersect that fissure. This lower segment measured 23 mm.

Left hemisphere.—The upper end of the fissure in this hemisphere was 81 mm. from the orbital pole and 65 mm. from the occipital pole, and in this side also it did not intersect the supero-mesial border. It ran downwards and forwards for a distance of 19 mm.; and was then interrupted by a bridging gyrus similar to that on the opposite side. In this case, however, there was a distinct groove on the surface of the gyrus in which lay a small vein which passed from the upper to the lower segment of the fissure. The lower portion of the fissure began in a bitid extremity, and it ran in nearly a straight direction downwards and forwards for a distance of 24 mm. towards the posterior horizontal limb of the Sylvian fissure, and on this side also it failed to intersect that fissure.

The distance of the upper end of the fissure from the termination of the calloso-marginal sulcus was 7 mm. on the right and 5 mm. on the left side.

Communications between the segments of the fissure of Rolando which is thus divided and adjacent sulci occur with considerable frequency.

Thus, in Spitzka's case (2) the ventral segment of the left fissure was connected with the lower part of the precentral sulcus, and in Beever's case (4) the right ventral segment was connected with a portion of the precentral sulcus. In Lattes' case (3) the dorsal segment of the fissure communicated with the upper part of the precentral sulcus; and in my own case, in the



right hemisphere a communication existed between the ventral segment of the fissure and the lower part of the precentral sulcus, and in the left hemisphere a similar connection was found between the dorsal segment of the fissure of Rolando and the precentral sulcus.

The frequency with which this connection exists suggests the idea that in such cases the necessary surface area of grey matter has been obtained by a folding of the ascending frontal convolution, to compensate for the loss of surface grey matter entailed in the persistence of the annectant gyrus which crosses the fissure of Rolando.

The other fissures and convolutions were well developed, but showed no special features requiring description.

The interruption occurred in this case, as is usual, between the two

genua of the fissure, in the position in which the convolutions which bound the fissure are usually connected together by a deep annectant gyrus. This deep annectant gyrus represents the interval which exists between the two primitive parts from which the fissure develops, and in which usually becomes submerged by the growth of the adjacent parts of the cortex (5). It may occasionally persist, as in the present case, and in such cases the fissure retains its primitive condition and remains in two pieces, an upper representing the upper third of the complete fissure, and a lower which represents its lower two-thirds.

The illustrations are tracings of the surface of the cerebral hemispheres taken by the periglyph.

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CONGENITAL OBLITERATION OF A PORTION OF THE ALIMENTARY CANAL. By DAVID WATERSTON, M.A., M.D., F.R.C.S.E.

THE occurrence of congenital obliteration of the alimentary canal has been recorded as taking place at different levels, and the condition appears to be one which occurs fairly often.

The specimen described below was sent by Mr Stiles to Professor Cunningham, who has kindly asked me to examine and report upon it. It was obtained from a female child aged three days, who had been admitted to the Royal Hospital for Sick Children, and was found to suffer from intestinal obstruction. The abdominal cavity was opened by Mr Stiles, and an artificial anus made into a loop of distended intestine; but the child did not recover from the operation.

Examination of the contents of the abdominal cavity after death showed the condition to be as follows:—The stomach was full, and normal in size and in shape. The duodenum and the jejunum for a distance of thirteen inches were normal in form and in position, but beyond that point the intestine was somewhat dilated; and at a distance of thirty inches from the pylorus there was an aperture in the wall where the artificial anus had been made. Beyond that point the intestine was not only greatly dilated, but the wall was also distinctly thickened, and apparently some hypertrophy of the muscular wall had taken place. Five inches beyond the artificial anus, the intestine terminated in a smooth, rounded extremity, which hung free within the abdominal cavity. At the same level the mesentery, which up to this point was normal in its arrangement, was divided nearly to its root, and a V-shaped gap had been produced in it. The free end of the intestine was smooth, but the rounded end was slightly whitened, as if the tissue were cicatricial in character.

The margins of the gap in the mesentery were smooth and rounded, but at the root of the mesentery were some enlarged glands.

The distal portion of the intestine was not readily found, as the remaining portion of the small intestine had become twisted in a peculiar manner. This remaining portion of the small intestine measured nearly eight inches in length, and commenced in a blind extremity which was bent upon itself and was attached by fibrous adhesions to the tip of

the vermiform process, which projected forwards from the right side of the cæcum. This blind end lay in the right iliac fossa, and the adjacent five inches below it was twisted in a spiral fashion round a peritoneal cord which proved to be a portion of the mesentery which had apparently occupied the V-shaped gap previously described.

The lower three inches of the small intestine were normal in position, and possessed a normal mesentery which was continuous with the mesentery of the upper segment.

One inch above the ileo-cæcal junction, the intestine was constricted by a peritoneal band which lay on the right side of the mesentery, and which passed from the mesentery to the wall of the intestine. This constriction had produced a dilatation of the intestine for one inch on the proximal side, and it looked as if the mesenteric band would in time have severed the intestine. No cause can be found to account for the production of this band, but it suggested that the obliteration of the intestine higher up had been produced by some similar condition.

There was no sign of a Meckel's diverticulum.

The cæcum was small but was well formed, and the colon showed no abnormality in its whole course, but was also rather small. The intestine had apparently developed in a normal manner, but had been severed, possibly by a mesenteric band near the origin of Meckel's diverticulum, and the mesentery had been torn nearly to its root. The distal portion had been rendered freely mobile, and probably peristaltic movement had produced a spiral twisting to the extent of three and a half turns in the direction of the hands of a watch. The free distal end had then become attached by adhesions to the tip of the vermiform appendix.

THE PHYSIOLOGY OF THE LATERAL ATLANTO-AXIAL JOINTS.

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the Children's Hospital, Great Ormond Street.*

IN the course of preparing material for an extensive examination of the injuries of the upper cervical spine, my attention has been attracted to several points in the physiology of the lateral atlanto-axial joints. In particular, the methods of rotation of the head, which takes place at these joints, have been carefully studied both under normal and abnormal conditions. The results are embodied in this paper. Briefly, it may be stated that natural rotation of the head is accompanied by an *eccentric* rotation of the atlas on the axis: which natural rotation, when converted into extreme or forcible rotation, has added to its eccentric rotation a further movement of *centric or symmetrical* rotation.

Anatomists have spent little time on the lateral atlanto-axial joints. As in the case of most other joints, they have given more attention to cataloguing and describing the various ligaments connected with them. Naturally, one is led to believe that these ligaments constitute the most important part of the joint. However, a little reflection will show that this is not so, and that the ligaments merely play a secondary and controlling part in the movements of the joint. Before entering into a discussion on the physiology of the joint, it is desirable that a few remarks should be made about the bony surfaces which enter into its formation. To the ordinary description little can be added; but as all the text-books agree in separating the descriptions of the articulating surfaces of the atlas and axis, it will be better to reproduce them together to show the structural discrepancies of the bony surfaces.

Professor Arthur Thomson of Oxford, in *Cunningham's Anatomy*, 1904, says of the inferior articular surfaces of the *atlas* that they display "a slight side-to-side concavity, though flat in the antero-posterior direction." Of the corresponding facets on the *axis*, the same authority says they are "slightly convex from before backwards and flat from side to side." Therefore the articular surfaces entering into the lateral atlanto-axial joints are incongruous, not being adapted accurately to each other. When seen from in front (fig. 1), the superior articular surfaces of the axis are

seen to be directed outwards and downwards from the base of the odontoid process. The head with the atlas is placed on two separate and oppositely inclined planes of the axis, on which it might balance. But these inclined planes have a third direction which prevents this mere static poise. Besides being inclined outwards and downwards, they are both inclined forwards, especially when the neck is flexed, so that the head and the atlas have a perpetual tendency to slip forwards.

This tendency cannot be prevented by any ligaments, as they would restrict the free movements of the joint. It is checked by the tonic action of the muscles of the neck, particularly of the short muscles. The movements at these lateral atlanto-axial joints are gliding movements which,

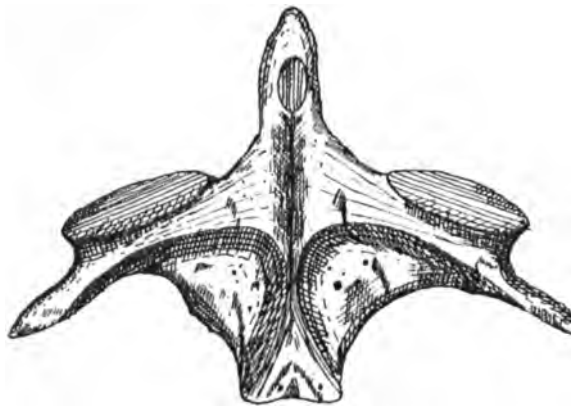


FIG. 1.—Anterior view of the axis, showing outward, downward, and forward inclinations of the superior and lateral facets.

owing to the threefold inclination of the articular surfaces, take place in three directions in space. Hence the capsular ligaments must be slack generally, or these movements would be much restricted. What appears to be the function of the ligaments is done, in reality, by the tonic action of the muscles of the neck up to a certain point, beyond which the former exert their controlling action.

With regard to the mechanism of the movement of rotation of the head, there is some general misconception. The view generally accepted is, that if the head is turned to the right, the right side of the atlas slides backward and the left forward. This is illustrated in fig. 2, diagrams I. and II.: AA and xx represent the transverse diameters of the atlas and axis respectively. It will be seen that the atlas rotates upon the mid-point of the axis or odontoid process as a centre. This mechanism is not true for the ordinary

easy movements; it is only true for forcible or extreme rotatory movements. The above view of the mechanism of rotation is that it is simple, whilst in reality it is both compound and complex.

In ordinary life the mechanism is different. When the head is turned to the right, the muscles of the neck fix, or practically fix, the right atlanto-axial joint. This is very simply done, as the only tendency which the right side of the atlas has, is to move up hill on the axis so that it is easily fixed against the inclined plane. The left side of the atlas moves down hill and forward on the axis. *The atlas pivots on the lateral atlanto-axial joint of the side to which the head is turned*; in the illustration given, on the right joint, and not upon the mid-point of the axis vertebra or the odontoid

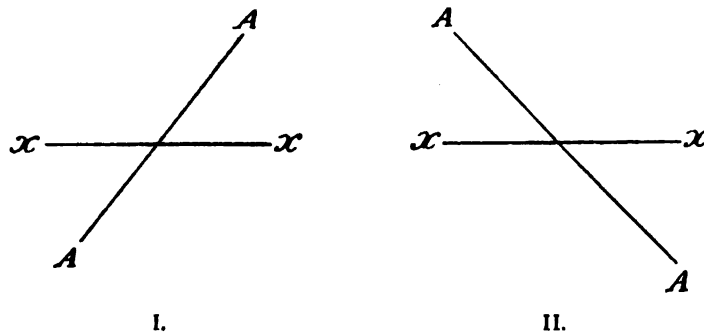


FIG. 2.—*xx*, transverse axis of the second vertebra; *AA*, transverse axis of the atlas. In I. the head is turned forcibly to the left; in II. it is turned forcibly to the right. This figure shows *centric* or *symmetrical* rotation of the atlas on the centre of the axis.

process, as illustrated in fig. 2. The difference of these two mechanisms is easily appreciated on comparing the diagrams of fig. 2 with those of fig. 3: *AA* and *xx* represent the same in both figures. The movements shown in fig. 2 may be called *centric* or *symmetrical* rotation of the atlas on the axis, and those of fig. 3 the *asymmetrical* or *eccentric*.

A further generalisation may be made. During its early and middle stages, rotation of the head is always done by means of asymmetrical eccentric rotation of the atlas on the axis (fig. 3). Extreme or forcible rotation is always effected by the symmetrical rotation of the already asymmetrally rotated atlas on the axis (fig. 2). The symmetrical rotation is superimposed on the asymmetrical. This superposition of different methods of rotation explains the larger size of the aperture for the spinal cord in the atlas as compared with those of the foramen magnum and the axis vertebra. Were it not so, rotation of the head would be a dangerous movement, liable

to lead to injury of the spinal cord. If the movements of the eccentrics of an engine are watched, the above argument is easily appreciated. A further point of interest is indicated: the mechanism of rotation of the head at the atlanto-axial joints is irregular, as it consists of two motions; first, an eccentric or asymmetrical, followed by a centric or symmetrical movement. It is of the greatest importance to the individual that there should be some fixed point to control this irregularity for the conversion of these two movements into each other. This is the prime function of the odontoid process.

In the execution of its most important and general function, a bone runs most likelihood of being injured. The odontoid process is most likely to be injured by the eccentric rather than the centric motion. It is broken by an exaggeration of this asymmetrical and eccentric movement. An

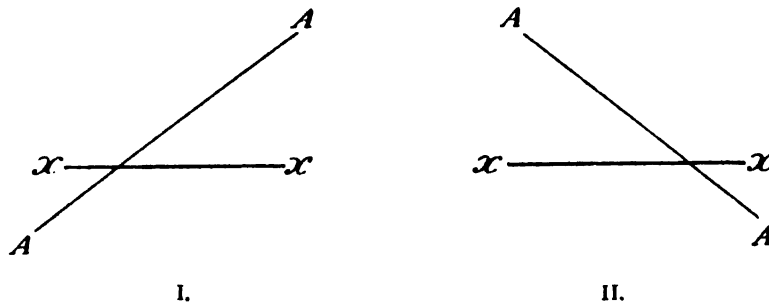


FIG. 3.—AA, *xx*, same as in fig. 2. In I. the head is turned to the left; in II. to the right. This figure shows *eccentric or asymmetrical* rotation of the atlas on the lateral atlanto-axial joints.

exaggeration of the same movement will cause—first, subluxation or partial dislocation of one of the atlanto-axial joints;¹ then unilateral dislocation of the joint;² and then fracture of the odontoid.³ It is of interest to refer in this place to the fact that we know fracture of the odontoid process to have occurred six times out of eight fatal and unilateral rotatory dislocations of the atlas.²

A simple observation may be quoted to illustrate further the eccentric and centric rotation of the atlas on the axis. If the tips of the forefingers are placed on the ends of the transverse processes of the atlas, found half-way between the angles of the jaw and the mastoid processes, and the head turned gently to the right, the transverse process of the right side will be felt to be stationary or to move very little backward when compared with

¹ *Transactions of the Clinical Society*, London, Nov. 1906.

² *Annals of Surgery*, 1907.

³ *Transactions of the Medical and Chirurgical Society*, 1907.

the large forward movement of the left transverse process. The movement of the right transverse process may be compared to the circumduction of the styloid process of the ulna during pronation and supination of the hand. If the gentle rotation of the head to the right is made forcible and extreme, the right transverse process will be felt to move backwards and be lost under the sterno-mastoid, showing the occurrence of the symmetrical rotation of the atlas on the axis.

By making alterations in the names of the sides as used above, similar observations can be made if the head is rotated to the left.

This point was excellently illustrated by a young man who was shown to the Clinical Society of London in February 1904. The left transverse process was easily palpable, but the right was not. He could turn his head to the right, but not to the left. The reason for this was, contrary to what

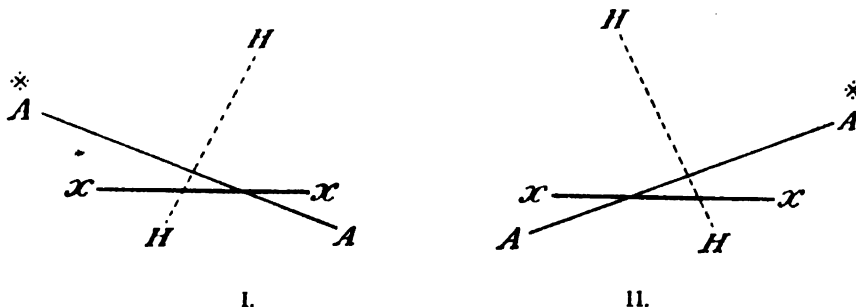


FIG. 4.—AA, *xx*, as in other figures; HH, long axis of head. Both I. and II. show eccentric rotation; I. to the right, II. to the left. In both cases the head is turned *with* the atlas. If the anterior side of the atlas * is dislocated and fixed, the head cannot be turned more to the front than the HH position. It can, however, turn to the other side. I. and II. represent the position when speaking, eyes front, assumed by cases of unilateral dislocation or subluxation of the atlas.

might have been expected, the left side of his atlas was dislocated forwards and therefore immovable, so that the head was already turned to the right. As the right joint alone was movable, it might have been expected that he could only rotate his head to the left of the middle line. But as in speaking to any person he kept his head as much turned to the front as possible, he was unable to turn it any further to the left, and was in consequence only able to move it to the right to this point. The two diagrams which are appended will explain this better than can be done in words.

In fig. 4, *xx* and AA represent the transverse axes of the atlas and axis as before, and HH the long axis of the head. In diagram I. the head is turned *with* the atlas, as in the position of eyes right. In diagram II. the head is turned as much as possible to the eyes-front position *on* the atlas.

Another case, shown at the Clinical Society in October 1905, showed by a similar test that one lateral atlanto-axial joint could work and the other could not. The left side of his atlas was partially dislocated forward and held there by some action of the muscles. He could move his head only to the right, to the position in which he held it when examined (diagram I. in fig. 4).

That the fixation of his neck was merely due to muscular action was shown by the administration of an anæsthetic. As soon as his muscles were relaxed, his head rolled over and became movable at once, the subluxation being reduced. Yet another interesting point was observed in his case, namely, he could only sleep lying on his belly. In any other position, sleep, by relaxing his muscles, caused his head to move and excited pain which woke him up. The anæsthetic was given about five weeks after the operation; and as the boy has recovered perfect movements, there cannot have been a full, but only a partial, dislocation, *i.e.* a subluxation of the atlanto-axial joint.

THE ARRANGEMENT OF THE SYNOVIAL MEMBRANE IN THE
PALMAR DIGITAL SHEATHS. By CHARLES R. WHITTAKER,
L.R.C.S., L.R.C.P., *Demonstrator of Anatomy, Surgeon's Hall,
Edinburgh.*

THIS investigation was undertaken in order to determine the precise relations that the synovial membrane bears to the individual tendons contained in the palmar digital sheaths. On account of the great difficulty involved in satisfactorily demonstrating the synovial coverings of the tendons in adult subjects, recourse was had to full-time embryos.

That the arrangement of the synovial membrane at birth coincides with that at maturity may be safely deduced, because :—

(1) The extent of the digital sheath is identical, *i.e.* from the base of the ungual phalanx to a point slightly above the head of the metacarpal bone.

(2) The sheaths have a similar situation with regard to the great palmar bursa, those of the index, middle, and ring fingers being isolated from it, that of the little finger usually communicating with it, and that of the thumb passing along its radial border and then beneath the anterior annular ligament into the forearm.

(3) The tendons of the flexor sublimis digitorum and the flexor profundus digitorum, as they lie in the sheath, present the same relations to each other as in the adult.

On opening up the sheaths our attention is first directed to the bands (vincula accessoria) which unite the tendons to each other and to the posterior wall of the sheath. The ligamenta brevia are two in number: the distal one, triangular in shape, continuous with the under surface of the flexor profundus digitorum; the proximal one, somewhat quadrilateral in appearance, passes from the synovial band which links together the tendons of the flexor sublimis digitorum near their insertion, to the back of the sheath.

Ligamenta brevia consist of a variable quantity of loose connective tissue covered by a film of synovial membrane. The free extremity is bifid (fig. 6). In well-injected specimens they are noticed to be vascular, a twig from the digital artery piercing the lateral wall of the sheath to enter them. The remaining vincula, that is, the ligamenta longa, are

rounded, cord-like bands composed of dense connective tissue surrounded by synovial membrane. Their number varies, but in the majority of cases we recognise two groups, single and paired. The former comprise one or two bands joining the deep flexor to the superficial flexor tendons; the latter pass from the flexor sublimis digitorum to the lateral margins of the posterior aspect of the sheath.

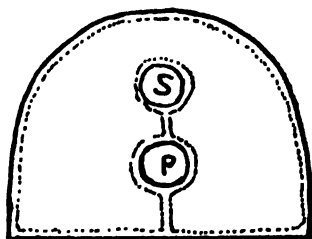


FIG. 1.

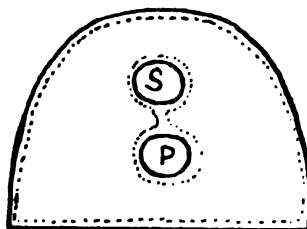


FIG. 2.

The synovial relations of the individual tendons are best displayed by a series of horizontal sections cut through the whole thickness of the sheath and its contents.

Fig. 1.—This section is taken through the palmar extremity of the sheath. Each tendon possesses a separate investment; the synovial membrane, after wrapping round the flexor profundus digitorum, becomes continuous with the layer lining the sheath.

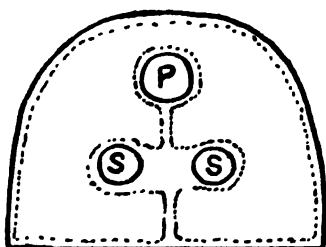


FIG. 3.

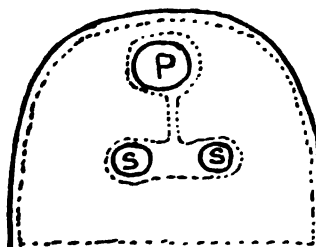


FIG. 4.

Fig. 2.—The arrangement here depicted is that found over the first phalanx, before the splitting of the flexor sublimis digitorum.

Fig. 3.—The flexor sublimis digitorum has divided. The synovial membrane, after investing the flexor profundus digitorum, passes over a ligamentum longum to enclose the split flexor sublimis digitorum, and from thence by means of a ligamentum brevum to line the sheath.

Arrangement of Synovial Membrane in the Palmar Digital Sheaths 157

Fig. 4 is made through the first interphalangeal joint. A film of synovial membrane connects the flexor profundus to the flexor sublimis digitorum. At this point there is no band going to the posterior part of the sheath.

Fig. 5 shows the relations found from the base of the second phalanx to the insertion of the flexor sublimis digitorum. The ligamentum brevum

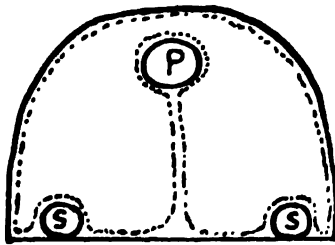


FIG. 5.

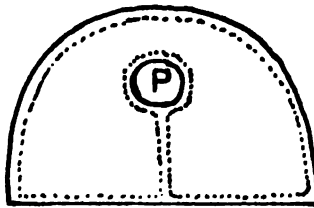


FIG. 6.

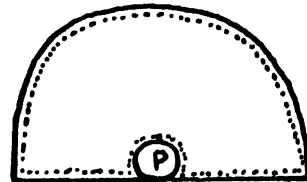


FIG. 7

of the flexor profundus reaches the back of the sheath and then rests upon the tendons of the flexor sublimis.

Fig. 6 is drawn through the distal half of the second phalanx, or through the second interphalangeal joint. Only the tendon of the flexor profundus digitorum is present with its ligamentum brevum.

Fig. 7.—This section is made through the base of the ungual phalanx. The synovial membrane covers the inner sheath wall and passes over the insertion of the flexor profundus digitorum.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND

JUNE 1906

THE Summer Meeting of the Society was held at Belfast on Friday, 1st June, 1906. The Society met at 10 A.M. and at 2.30 P.M. The President, Professor J. SYMINGTON, F.R.S., occupied the chair. There were eighteen members and twenty-nine visitors present.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were elected members of the Society:—
A. R. THOMPSON, M.B. (Irel.), F.R.C.S.; P. SARGENT, M.B. (Cantab.), F.R.C.S.;
R. BRUCE YOUNG, M.A., M.B., C.M. (Glasgow).

The following communications were made to the Society:—

1. Dr JOHN CAMERON exhibited a series of micro-photographs illustrating *the development of nerve fibres*.

2. *Dr JOHN CAMERON and Dr J. D. LICKLEY reported a case of an *abnormal arrangement of the peritoneum*.

3. Professor FAWCETT exhibited specimens showing:—

(a) Double ossification of the patella, the centres being vertically disposed.

(b) A specimen of the atlas from a subject eighteen years of age, showing that the transverse processes are completed by epiphyses

(c) A series of reconstruction models illustrating the growth of the lower jaw. One from a 19 mm. foetus, another from a foetus of 21 mm., another from one of 23 mm., and one from a foetus of 42 mm.

(d) A series of sections of the central nervous system, mounted in a

* This paper was published in full in the October number of the *Journal of Anatomy and Physiology*, 1906.

frame which could be rapidly passed through a carrier to the lantern, and so demonstrated directly to a class of students.

(e) Specimens to illustrate the ossification of the ribs, showing that from the 1st to the 5th or 6th the tubercle is formed by two centres, that down to the 9th it is formed by one centre, and that below the 9th it is not independently ossified.

(f) Lantern slides of the septum of the nose, showing that during the 110 mm. stage the Jacobsonian cartilage undergoes ossification, producing a hitherto undescribed bone in the septum.

(g) Lantern slides from photo-micrographs, showing that the ethmoid first commences to ossify in a process which passes outside the nasal duct to reach the nasal process of the superior maxilla.

(h) Lantern slides illustrating the ossification and development of the upper jaw.

4. Professor A. FRANCIS DIXON referred to a *frequent retention of the blood channel described by Luschka in cases of chondrodystrophia foetalis*, and exhibited a series of *chondrodystrophic skulls*, each of which showed on both sides a retention of venous communications between the intra-cranial and superficial veins in the neighbourhood of the glenoid fossa. The crania were all from individuals who were the subjects of typical chondrodystrophia foetalis or achondroplasia. Three were adults—one female and two males,—and one was a full-time foetus. In each of the four specimens the characteristically contracted basis cranii and the shortened limb bones were strikingly shown. Two of the adults and the foetal specimen were kindly lent by Professor E. H. Bennett.

The venous communications between the petrosal and lateral sinuses, and the more superficial veins near the condyle of the lower jaw, first received attention from Luschka, and were regarded by him as representatives of the primitive jugular vein. In recent years this interpretation of the persistence of these venous channels has been questioned, and there is at present much evidence to show that Luschka's view must be modified.

From an examination of the specimens exhibited, it would appear that a retention of the venous communication between intra- and extra-cranial blood channels, in the region of the glenoid fossa, is common in, if not characteristic of, chondrodystrophia foetalis, although it is very rare in normal individuals.

5. *Mr F. G. PARSONS read a paper on *the Topographical Anatomy of the Upper End of the Tibia*.

* This paper was published in full in the October number of the *Journal of Anatomy and Physiology*, 1906.

6. Professor PATTEN showed a brain in which there was *absence of the Corpus Callosum*.

7. *Professor ELLIOT SMITH showed a number of specimens and read a paper on *the Folding of the Visual Cortex in the Primates, and on the Significance of the Cerebral Sulci*. He pointed out the usefulness of a careful naked-eye examination of the cerebral cortex, whereby, for example, the precise extent of the visual striate area could be readily defined; and he pointed out the errors which had arisen through a purely histological examination of different parts of the cortex. He described the naked-eye appearance of the visual cortex, and pointed out how its extent corresponded with different sulci in carnivora, ungulates, lemurs, lower monkeys, and anthropoids; and, finally, he described its limits in the human brain, in which he recognised its division into three areas, which he styled respectively, (1) *striate*, (2) *peri-striate*, and (3) *para-striate*.

8. Dr ARTHUR KEITH introduced a discussion on *the Muscular Connections between the Auricles and Ventricles of the Heart*, and demonstrated

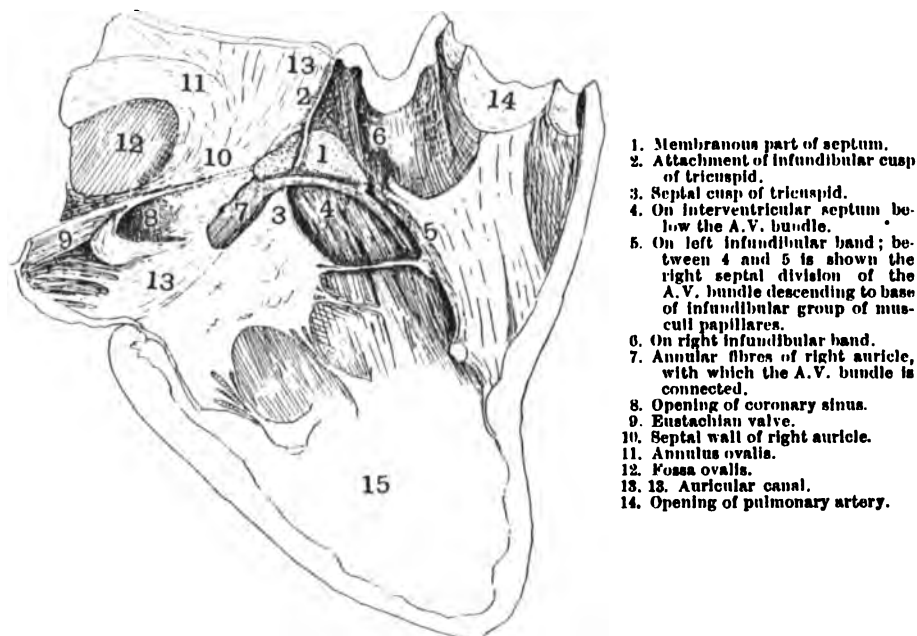


FIG. 1.—To show position and relationships of the A. V. bundle.

the bundle of His. The President, Professor Robinson, Professor Fawcett, Dr Bruce Young, and others joined in the discussion.

* This paper will appear in a subsequent number of the *Journal of Anatomy and Physiology*.

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9. Professor ELLIOT SMITH read a paper in which he discussed (a) asymmetry of the brain and skull; (b) abnormalities of the pyramidal tracts; (c) symmetrical thinning of the parietal bones in ancient Egyptians.

10. Professor ELLIOT SMITH, on behalf of Mr DOUGLAS DERRY, read a paper on *Platygnemiu in the Tibia*.

11. *Dr H. M. JOHNSTON read a paper and demonstrated some beautiful preparations of the bones of the hand in different positions.

The members were entertained by the President of the Society, as well as by the President of Queen's College, Belfast.

Many members joined in an excursion on 2nd and 3rd June to the Giant's Causeway and other places of interest.

* Part I. of this paper appears in full in the present number of the *Journal of Anatomy and Physiology*.

JOURNAL OF ANATOMY AND PHYSIOLOGY

DESCRIPTION OF A HUMAN EMBRYO OF TWENTY-THREE
PAIRED SOMITES. By PETER THOMPSON, M.D., *Professor of
Anatomy, King's College, London.* (PLATES I.-III.)

THE embryo which forms the basis of this work came from Dr Robert Meyer's collection in Berlin. Sent to Professor Keibel, who was accumulating material for his forthcoming *Normentafeln* of human embryos, the specimen was most kindly lent to me with the object of making a model whilst I was at the Anatomical Institute in Freiburg during the summer of 1906. Working with this specimen, I had an excellent opportunity of becoming acquainted with the reconstruction of embryos by the wax-plate method, as carried out so successfully in that University.

The embryo, obtained at an operation, was recorded as 2.5 mm. long, and was cut transversely into 488 sections, each 5 μ in thickness, and stained with borax-carmin.

In making the model, every other section was drawn, enlarged 100 diameters, and the wax plates were made 1 millimetre in thickness. When the plates had been cut and laid in position, it was found, owing probably to the hot weather and the weight of wax, that the total height of the model was only 220 millimetres, and, in order to correct the error, 24 additional wax plates were made, duplicates of every tenth section, and introduced into the series. In this way the total length of the model was brought up to 244 millimetres, corresponding to the 244 sections used, which indicates a shortage of less than 3 per cent, when compared with the 250 millimetres, the absolutely accurate measurement which the enlargement should have been, taking the length of embryo as 2.5 mm. The difference is probably due to a slight shrinkage, which would most probably occur in preparing the specimen for cutting. It may be stated here that the embryo is histologically in excellent condition, mitosis being readily observed in the multiplying cells, and there seems no

valid reason for doubting that the specimen is a normal one. In addition to the model of the whole embryo and its yolk sac, other models were made of special organs, namely, the heart and its endothelial tube, the brain, a part of the alimentary canal, and the septum transversum.

It may be noted that the embryo described in this paper resembles in many ways His's embryo Lg., which was 2.15 mm. in length and estimated to be about fifteen days old.

DESCRIPTION OF MODELS.

The Embryo and its Yolk Sac.

The head is small, somewhat flattened from above downwards, and pointed. At the side, the opening of the otocyst externally is seen over the

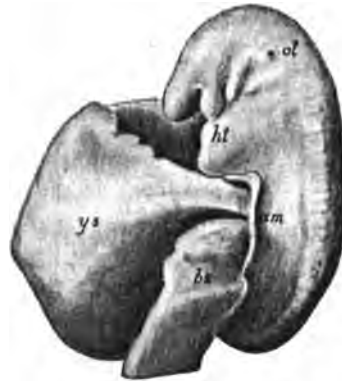


FIG. 1.—Wax cast of embryo and yolk sac. $\times 18$.

ot., opening of otocyst; ht., heart; am., root of amnion; b.s., body stalk; y.s., yolk sac.

upper end of the second post-oral branchial cleft. Anteriorly, two slight but well-marked bulgings indicate the position of the optic vesicles, between which is a depressed area corresponding to the anterior neuropore, completely closed, but still recognisable in the sections by the continuity of the general ectoderm and the neural ectoderm. The mouth is a narrow transverse cleft, at the bottom of which the bucco-pharyngeal membrane is seen, perforated in two or three places. Behind the mouth three branchial clefts are seen externally, and the large prominence below it indicates the position of the heart. There is no trace of limbs.

The alimentary canal is in wide communication with the yolk sac through the vitelline duct, which, with the body stalk, occupies the umbilical orifice. The yolk sac, about as large as the embryo, is globular in form and presents two marked depressions, an upper one for the accom-

modation of the head, and the prominence of the heart, and a lower one for the tail and the body stalk. The body stalk, about the same thickness as the vitelline duct, below and to the left side of which it is placed as it emerges from the umbilical orifice, is directed forwards, downwards, and outwards to join the chorion. In the caudal region the back of the embryo curves to end in the prominent tail which is sharply flexed and turned to the right, so that the embryo appears to be somewhat spirally twisted. Here the neural groove is not yet closed, giving rise to a posterior neuropore, a gutter, shallow at first but gradually deepening up to the point where it becomes continuous with the central canal of the spinal cord just in front of the bend of the rump. The cloacal membrane is clearly distinguishable on the side opposite to the neural groove, and the free extremity of the cauda is received into a depression on the right side of the body stalk, into a little cul-de-sac formed by the amnion. At the curve of the rump the mesoblastic somites are recognisable as distinct protuberances, whereas in the region of the back and the neck they are much less prominent.

Root of Amnion.—Caudalwards, the root of the amnion is prolonged on to the dorsal aspect of the body stalk, where it has a V-shaped attachment. The two limbs are continued upwards on either side of the umbilical orifice, that on the right passing between the tail and the stalk and forming, as mentioned above, the recess into which the tip of the tail is received. At the upper (anterior) boundary of the umbilical orifice the amnion is reflected along a line which runs transversely across the embryo at the lower end of the heart prominence, and in this way the attachment of the root of the amnion is completed. It will thus be seen that, in this embryo, a very small part only of the body stalk, on its dorsal surface, is covered with ectoderm.

NERVOUS SYSTEM.

The nervous system is closed except in the region of the tail, where, as already noted, there is a posterior neuropore. Whilst, therefore, the caudal portion of the neural tube is the last part to close in this embryo, this is not invariably the rule. Indeed there seems to be considerable variations both with regard to the last place of closure of the tube, and the time at which the closure is complete.

According to Hertwig's *Handbuch*, the medullary groove in the human embryo at the end of the second week is not yet closed, and attention is drawn to the fact that the series, from the second week to the time when the closure is complete, have not yet been described. The specimen under consideration forms another link in that series, of which a few may be briefly noted.

In Eternod's (1) embryo of eight paired somites and a length of 2.1 mm., the medullary folds are united in the cervical and thoracic regions, but the groove is open in front and behind. In Kollmann's embryo (von Bulle) (2) of thirteen paired somites and a length of 2.3 mm., the groove is closed posteriorly, but open for a considerable distance in front. In Janosik's (3) embryo of twenty-four paired somites and a length of 3 mm., the whole length of the medullary canal is closed except in front, in the neighbourhood of the cerebral vesicles, where an incomplete fusion of the edges of the medullary tube is visible. In the embryo described by His (4), 2.4 mm. long, the medullary groove, with the exception of a short portion, is closed. Lastly, J. L. Bremer (5), in an embryo of 4 mm., which he has

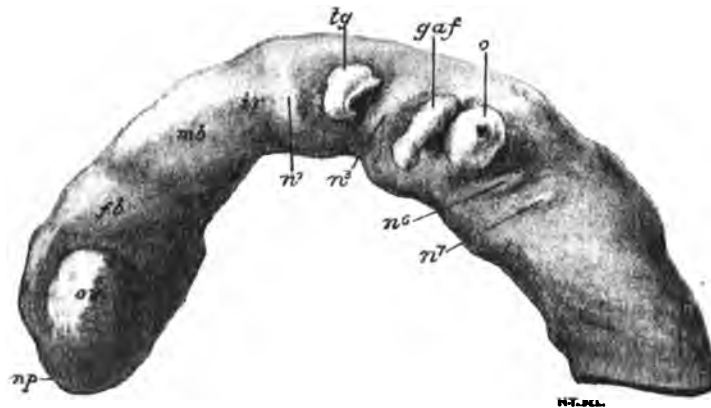


FIG. 2.—Model of brain and part of the spinal cord. $\times 75$.

n.p., place of anterior neuropore (closed); *o.v.*, optic vesicle; *f.b.*, fore-brain; *m.b.*, mid-brain; *l.r.*, isthmus rhombencephali; *n.1* *n.2* *n.3* *n.4* *n.5* *n.6* *n.7*, neuromeres; *t.g.*, trigeminal ganglion; *g.a.f.*, ganglion acoustico-faciale; *o.*, otocyst.

recently described, found the neural groove open both in front and behind. With differences such as these, it seems impossible to state any definite time, length of embryo, or the number of somites with which complete closure might be associated.

The brain consists of three cerebral vesicles. The fore-brain, with its optic outgrowths, but with no trace of cerebral hemispheres or hypophysis; the mid-brain, the smallest of the three, and distinctly marked off, both in front and behind, by two constrictions; and the hind-brain, larger than either of the preceding vesicles, and moreover distinguished by exhibiting a series of neuromeres. These are seven in number, of which the second, third, fourth, and fifth are the most prominent.

Certain important structures are in relationship with these neuromeres. The trigeminal ganglion, somewhat pear-shaped, is placed opposite the

second; the ganglion acoustico-facialis is placed opposite the fourth; and the otocyst opposite the fifth. The otocyst is a hollow rounded vesicle, with a small aperture opening on to the surface at the side of the head: it is in contact mesially with the hind-brain. The ganglion of the ninth and tenth cranial nerves is not yet visible, and this may explain the imperfect differentiation of the sixth and seventh neuromeres, opposite which the ganglia of these nerves normally develop.

The number of cases in which seven neuromeres have been observed in association with the hind-brain are now so numerous that the arrangement may be considered normal. C. Bradley (6) in 1904 described the series in the pig, and Broman (7) in 1895 fully described the neuromeres of the hind-brain in a human embryo of three millimetres.

The flexures of the brain in this specimen are so different from those usually described that a brief reference must now be made to them.

At the isthmus rhombencephali, the district between the mid- and hind-brains, there is a prominent flexure, which also involves the anterior extremity of the notochord. The mid-brain and the fore-brain are bent downwards, but there is no flexure of the fore-brain round the anterior end of the notochord. Its place is taken by the flexure at the isthmus, and the head-bend of the embryo corresponds with it.

A pontine flexure occurs between the anterior part of the hind-brain, which is placed horizontally, and the posterior portion which slopes downwards and backwards. The angle of the bend is open downwards, and is placed opposite the fourth neuromere.

This bend does not correspond with the pons flexure formed later as a result of a ventral bending of the floor of the hind-brain.

The neck flexure is a very gradual one, and there is no indication of any constriction separating the brain from the cord.

Two of the flexures just described are so different from those universally regarded as primary cerebral flexures, that one hesitates to go further than simply place them on record. One point, however, may perhaps be added. The model shows the brain in a very early stage of development, before the hemispheres or the hypophysis have appeared. Is it not possible that there may be certain flexures, of a temporary character, which precede the primary flexures usually described? It will be interesting to see if future models of embryos at this age exhibit any flexures at all resembling them.

NOTOCHORD AND SOMITES.

The notochord lies close to the ventral surface of the spinal cord and brain, the general curve of which it follows. At its cephalic end it

terminates opposite the bucco-pharyngeal membrane under the mid-brain, at its junction with the fore-brain. This part is distinctly flexed in association with the bend of the neural tube at the isthmus rhombencephali, and a little further back, *i.e.* under the foremost neuromeres of the hind-brain, it is thicker than elsewhere, and here it retains a direct connection with the entoderm. At its caudal end the notochord can be traced round the region of the rump into the tail, where it ends indistinctly by joining the undifferentiated mesoderm of that structure.

There are twenty-three pairs of somites, of which the first three, or three and a half, may be regarded as occipital, the remainder constituting the trunk somites, of which there are twenty. The twenty-first trunk somite is just beginning to form, but there is a region, including the tail, in which the mesoderm is not yet segmented.

ALIMENTARY CANAL.

The pharynx is separated from the mouth by the bucco-pharyngeal membrane, which is already perforated, but there is no trace of the diverticulum of Rathke.

Behind the membrane the pharynx is relatively capacious in a transverse direction, and exhibits on each side four pouches, of which the first is the largest, the succeeding ones diminishing in size from before backwards. They are compressed antero-posteriorly, and the first three terminate in blunt extremities, which are more or less vertically disposed. The fourth pouch is very small and pointed. As stated above, there are only three depressions externally behind the mouth, forming the branchial clefts.

In the roof of the pharynx there is a prominent ridge continuous with the notochord, and connected with the floor is a small, hollow, rounded diverticulum, the median rudiment of the thyroid body. It opens into the pharynx by an exceedingly small aperture some distance behind the remains of the bucco-pharyngeal membrane, and opposite to the first pharyngeal pouch. There is no indication of the tuberculum impar or the furcula.

Behind the fourth pair of pharyngeal pouches the alimentary tube suddenly narrows, and becoming compressed laterally, forms a cleft-like lumen directed antero-posteriorly. The part of the tube, however, where the gradual change from a transversely disposed lumen to an antero-posterior one is manifest, is particularly interesting and important, as being the region at which the anlage of the lungs may be recognised. The two lung buds are already indicated as outgrowths from the entodermal tube, the epithelium of which is markedly thickened in this situation, and they are situated a short distance behind the fourth pair of pouches. The left

lung bud, more prominent, is placed in advance of the right, and both are growing towards the pleural passages, the communications between the pericardial and peritoneal portions of the coelom. The lung rudiments are placed opposite either the hindmost occipital or first trunk somite in front (cephalad) of the dorsal mesocardium of the heart.

It is significant that the lung buds in such an early embryo should already be bilateral, particularly in connection with the debatable question of the nature of the lung anlage and the changes leading to the formation of the lung sacs. Whilst, as J. W. Flint (8) has recently pointed out, there is almost unanimity of opinion on the question of an unpaired origin, amongst those who have contributed to our knowledge of the development of the lungs, there are, however, a few who believe in a paired anlage, and regard the mammalian respiratory apparatus as arising from primitively paired structures. Inasmuch that the paired buds are already present in this embryo, it lends some support to the latter view.

It is a very interesting question, seeing that a paired anlage for the lungs would bring them into line with the branchial pouches. "The lungs," writes J. M. Flint (8) when dealing with this view, "while not representing actually existing branchial pouches (would) indicate the reappearance of endodermic evaginations of the head gut which have carried gills among the ancestors of vertebrates."

Below the origin of the lung buds is the anlage of the oesophagus and stomach, and in this part of the tube, beginning with the region where the lung rudiments are found, and extending backwards as far as the liver bud, the epithelial lining is markedly thickened. Opposite the third and fourth trunk somites the liver is seen growing into the septum transversum. The hepatic bud is a median structure with thick walls enclosing a cavity in communication with the alimentary canal. There is no trace of the pancreas.

The succeeding part of the alimentary canal is in wide communication with the yolk sac, and then follows the hind gut, a very narrow part with a rounded lumen. This terminates in the cloaca, a relatively capacious cavity, pear-shaped in transverse section, opposite the point of junction with the allantois, triangular in section, beyond this, towards the tail gut. The Wolffian ducts have not yet reached the cloaca, but terminate in connection with the ectoderm some distance from it.

Along its greater curvature the cloaca is in relation with the notochord, and along its lesser curvature it comes into contact with the ectoderm at the root of the tail to form the cloacal membrane. The terminal part of the gut extends beyond the membrane into the tail, and forms the post-anal gut.

Connected with the cloaca is the allantois, an extremely small tubular structure which extends outwards for some distance through the umbilical orifice embedded in the mesoderm of the body stalk. At its cloacal end it is somewhat funnel-shaped, and at the opposite extremity, where it ends blindly, is a small swelling bent upon itself.

The allantois at its origin is situated, like the cloaca, between the two primary caudal arches. From this origin it is directed dorsalwards, and forwards, towards the umbilical orifice, being placed between the umbilical arteries. This part of the duct is very narrow and of fairly uniform calibre until it changes its direction, and runs ventralwards through the umbilical orifice. At the bend is a well-marked swelling, and another one is present just outside the orifice, a short distance from the blind extremity. This part of the tube is also accompanied by the umbilical arteries, which fuse to form a single vessel soon after they pass out of the embryo into the body stalk.

EXCRETORY SYSTEM.

The excretory system, which is not shown in the model, consists of three parts (1) the Wolffian duct, (2) the rudimentary pronephric anlage, and (3) the mesonephric anlage.

The Wolffian Duct is situated close to the ectoderm, as is shown in Keibel's model of an embryo 15-18 days old. It begins as a duct with a distinct lumen opposite the eighth trunk somite and extends uninterruptedly as far as the twentieth trunk somite, where it ends by joining the ectoderm. This point is some distance from the cloaca, and coincides with the end of the differentiated muscle somites and the mesonephric anlage. Neither the muscle segments nor the mesonephric anlage are differentiated beyond the twentieth trunk somite, but as the formation of these structures is continued, the Wolffian duct, it may be assumed, likewise becomes differentiated, and, extending caudally, opens into the cloaca. In the embryo described by Bremer (5), which measured 4 mm., the duct of the right side opened into the cloaca; on the left side, however, it did not reach so far, but ended blindly.

The Rudimentary Pronephros.—Situated in the neck region, opposite the sixth, seventh, and eighth trunk somites, there is, on each side, two or three rudimentary tubules, not connected by any duct, but communicating with the coelom, each by a funnel-shaped passage or "trichter." This group of rudimentary tubules probably represents the pronephros, and it is separated by a distinct interval from the anlage of the mesonephros, which lies posterior to it.

Pronephric rudiments have been described by Keibel (9) in the embryos

of apes, tarsius, and Man; by Tandler (10) in eight out of twelve human embryos of 5–20 mm. always at the level of the sixth and seventh segments; by S. P. Gage (11), in a human embryo of 3 mm.; and also by McCallum (12), Bremer (5) and others.

The Anlage of the Mesonephros begins opposite the eighth trunk somite, i.e. the same segment opposite which the Wolffian duct begins to have a lumen. At this stage of development the mesonephros consists of a series of segmental vesicles with rudimentary nephrostomes. They are close together and connected with the Wolffian duct, but there is no definite numerical agreement with the mesoblastic somites. The mesonephric tissue is connected with the somites, and can be traced caudally as far as the latter are differentiated. There are no glomeruli.

THE VASCULAR SYSTEM.

The Heart.—The specially interesting feature of this model is the clear indication of a fourth chamber—the bulbus cordis¹—to which A. Keith (13) has recently drawn attention. Besides the sinus venosus, auricle, and ventricle, the three parts which are supposed to give rise to the whole heart in the adult, there is undoubtedly a chamber on the right side, extending between the ventricle and the aortic stem. Its summit forms the highest part of the heart, and rises to the right side of the neck region. A. Greil (14) of Innsbruck has already published an account of its embryology in birds and reptiles, and traced its subsequent history; and A. Keith (13) has shown that many malformations of the human heart, hitherto believed to be the result of foetal endocarditis, are really due to mal-development, or arrest of development of this fourth chamber.

In its general configuration the heart has an S-shaped form, the various parts of which are already foreshadowed, and disposed to some extent in the same relative position as in the adult. The four parts of the tube which can be recognised are the sinus venosus, the auricle, the ventricle, and the bulbus cordis, and it will perhaps be most advantageous if each of the divisions be separately considered.

Sinus venosus.—The sinus venosus consists of two horns, right and left, united by a transverse connecting piece. It constitutes the hindmost part of the heart, and is in intimate relation with the septum transversum, the latter forming a distinct shelf between the two horns dorsally, and the ventricle ventrally. The right horn is larger than the left, and on each side the summit or blind end extends into the pleural passage. Each horn

¹ The name proposed by A. Langer for the two homologous structures, the conus arteriosus of anamniota and the bulbus arteriosus of the amniota.

receives, on its lateral aspect, a very short duct of Cuvier, and the umbilical vein. The vitelline vein, on the other hand, opens into the posterior (caudal) end of the sinus venosus, which appears to be a direct continuation of it. The transverse connecting piece runs from the left horn to the right horn; it is placed immediately ventral to the gut, and between the dorsal mesocardium in front and the septum transversum behind. The right horn communicates freely with the right side of the common auricle, but there is no indication of the formation of the right and left venous valves.

The Auricle.—The auricular chamber is placed dorsal to the aortic stem, which is received into a concavity on its ventral surface. The auricular

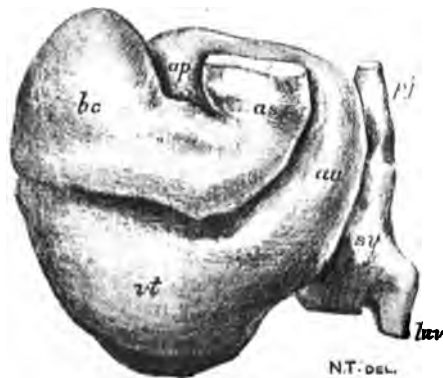


FIG. 3.—Model of heart, from the front and slightly from the left side. $\times 75$.

p.j., primitive jugular vein; s.v., sinus venosus (left horn); l.u.v., left umbilical vein; a.p., right auricular appendix; a.s., aortic stem; b.c., bulbus cordis; vt., ventricle; au., auricle.

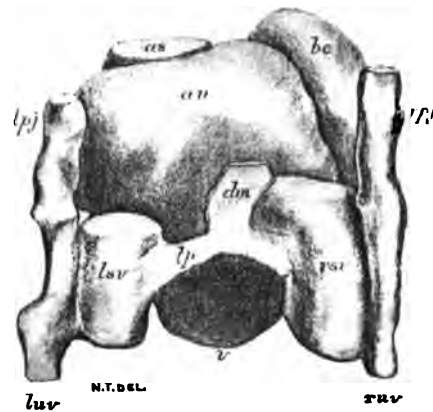


FIG. 4.—Model of heart, seen from behind. $\times 75$.

r.p.j., right primitive jugular vein; r.s.v., sinus venosus (right horn); r.u.v., right umbilical vein; v., ventricle; d.m., dorsal mesocardium; t.p., transverse connecting piece; l.s.v., sinus venosus (left horn); l.u.v., left umbilical vein; l.p.j., left primitive jugular vein; au., auricle; b.c., bulbus cordis; a.s., aortic stem. (Posterior cardinal vein not shown, but point of junction with the lower end of the primitive jugular vein is seen as a rounded knob.)

appendices are already indicated, particularly the right, which projects ventrally between the bulbus cordis and the aortic stem.

On the right side of the auricle is the bulbus cordis, a narrow cleft separating the two structures, and on its dorsal surface it gives attachment over a somewhat oblong-shaped area to the dorsal mesocardium. As the auricle is traced leftwards and downwards, the tube somewhat narrows, and a slight constriction indicates the site of the auricular canal.

The Ventricle.—The ventricle begins on the left side and forms the lowest part of the heart or apex. From this it passes to the right in contact with the septum transversum, which is sloped for its reception, and finally it bends forward to become continuous with the bulbus cordis.

The Bulbus cordis.—This is the part of the tube situated between the ventricle and the aortic stem. At its commencement it is a fairly capacious chamber, but traced onwards it narrows to become continuous with the aortic stem, the two forming a V-shaped figure on the anterior (ventral) aspect of the heart. According to Greil (14) and Keith (13) this fourth chamber of the heart becomes completely incorporated in the right ventricle to form the infundibulum.

Endothelial Tube.—A special model of this was made (fig. 5) to show its relationships to the muscular tube of the heart. The two are separated by an interval, particularly in the ventricle, the bulbus cordis, and the aortic stem, so that at this stage of development there are really two tubes, endothelial and muscular, one inside the other.

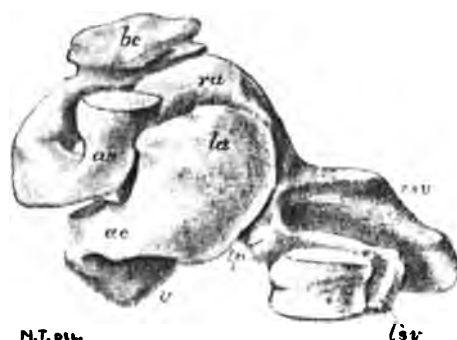


FIG. 5.—Model of endothelial tube of heart. $\times 75$.

b.c., bulbus cordis; r.a., right auricle; l.a., left auricle; a.c., auricular canal; v., ventricle; a.s., aortic stem; t.p., transverse connecting passage of sinus venosus; r.s.v. and l.s.v., two horns of sinus venosus.

The endothelial tube shows constrictions at the auricular canal, at the ventricular end of the bulbus cordis, and at the aortic end of the bulbus cordis. There is also a most obvious constriction in the bulbus cordis, not however at right angles to the tube, but in line with it, and disposed in such a way as to constrict the entrance of a pouch which occupies the highest part of the bulbus, and opens into the rest of the tube by a narrow orifice. It is difficult to say what the significance of this constriction may be, but it is possibly associated with the series of events leading to the incorporation of the bulb with the right ventricle. Finally, it may be noted that the endothelial tube rises higher on the right side of the auricle than on the left.

Arteries.—From the aortic stem, the arterial arches, two in number on each side, have a radial disposition as they pass into the first and second visceral arches. The dorsal aortæ pass backwards on either side of the

notochord: at first separated, but gradually approaching one another, they eventually fuse to form a single vessel, ventral to the notochord. The fusion takes place opposite the seventh trunk somite, and the two vessels continue as a single stem up to the thirteenth trunk somite, when they again separate to form the two primary caudal arches. The umbilical arteries accompany the allantois, the right distinctly smaller than the left, and finally the two vessels join together to form a single trunk within the body stalk.

Veins.—The vitelline veins, returning the blood from the plexus on the yolk sac, form two well-developed vessels placed one on either side of the alimentary canal, and in close relation with the dorsal part of the septum transversum. They open into the hinder end of the two horns of the sinus venosus, mesial to the termination of the umbilical veins.

The umbilical veins entering the embryo by the body stalk run in the body wall on either side of the umbilical orifice. Reaching the venous end of the heart, each opens into the lateral aspect of the sinus venosus in common with the duct of Cuvier. The two vessels are nearly equal in size, and it is worthy of mention that the vein on each side receives a small tributary, soon after it enters the embryo, from that part of the body wall corresponding to the site at which the bud of the hind limb subsequently grows out.

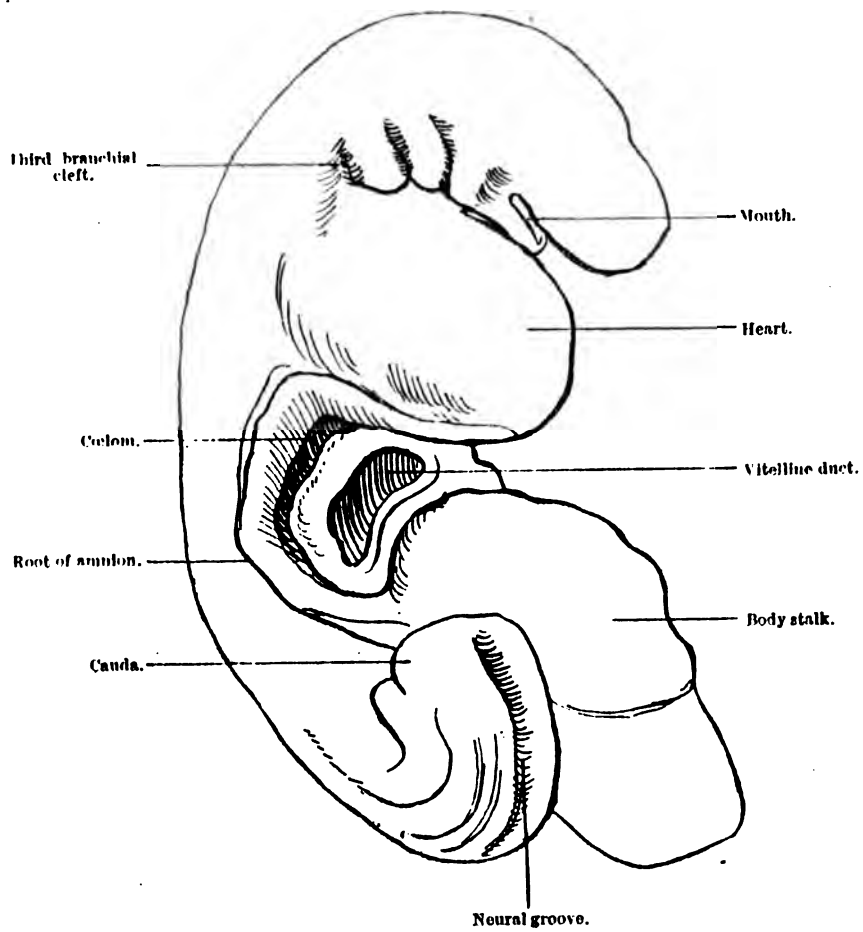
The primitive jugular vein begins in the neighbourhood of the otocyst, and, becoming more superficial as it is traced backwards, is finally joined by the posterior cardinal vein to form the duct of Cuvier. The latter is a short trunk, which opens into the sinus venosus.

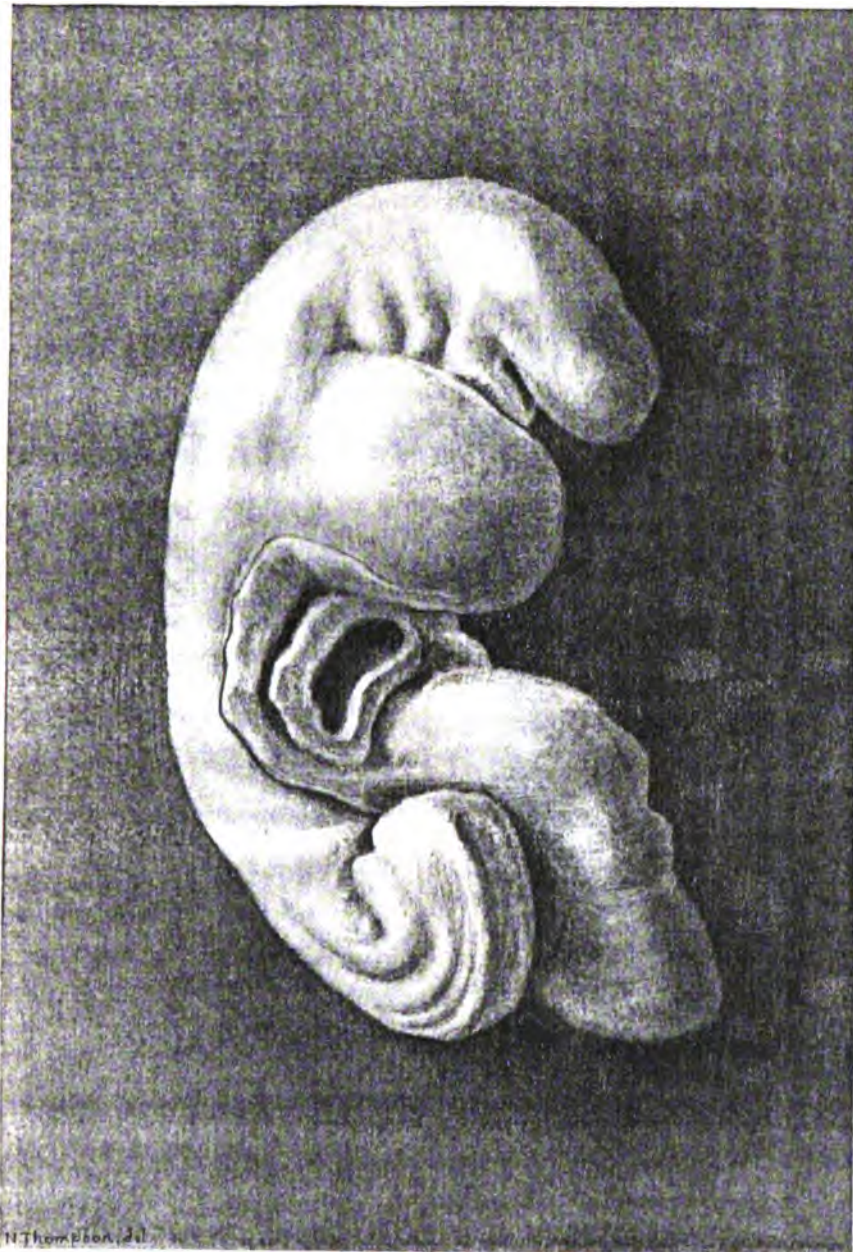
A further note on the septum transversum and the liver will be published subsequently.

In conclusion, I should like to express my warmest thanks to Professor R. Wiedersheim for placing at my disposal a place in his laboratory, and especially to Professor Keibel for lending me this rare and valuable embryo, and for his kindly advice and criticism whilst the models were being made. My thanks are also due to Dr Robert Meyer, to whom the specimen belongs.

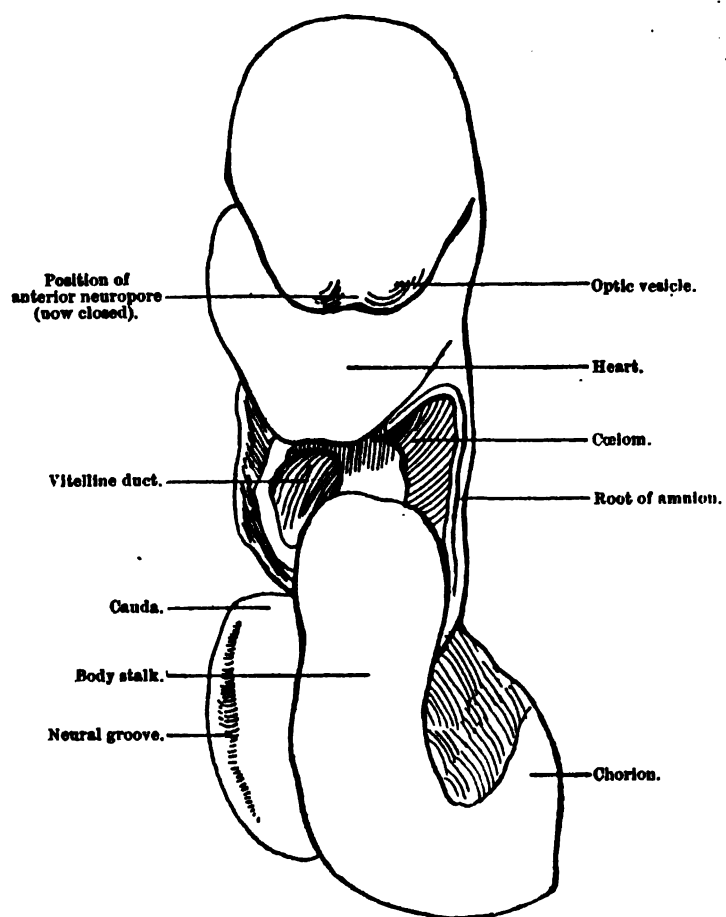
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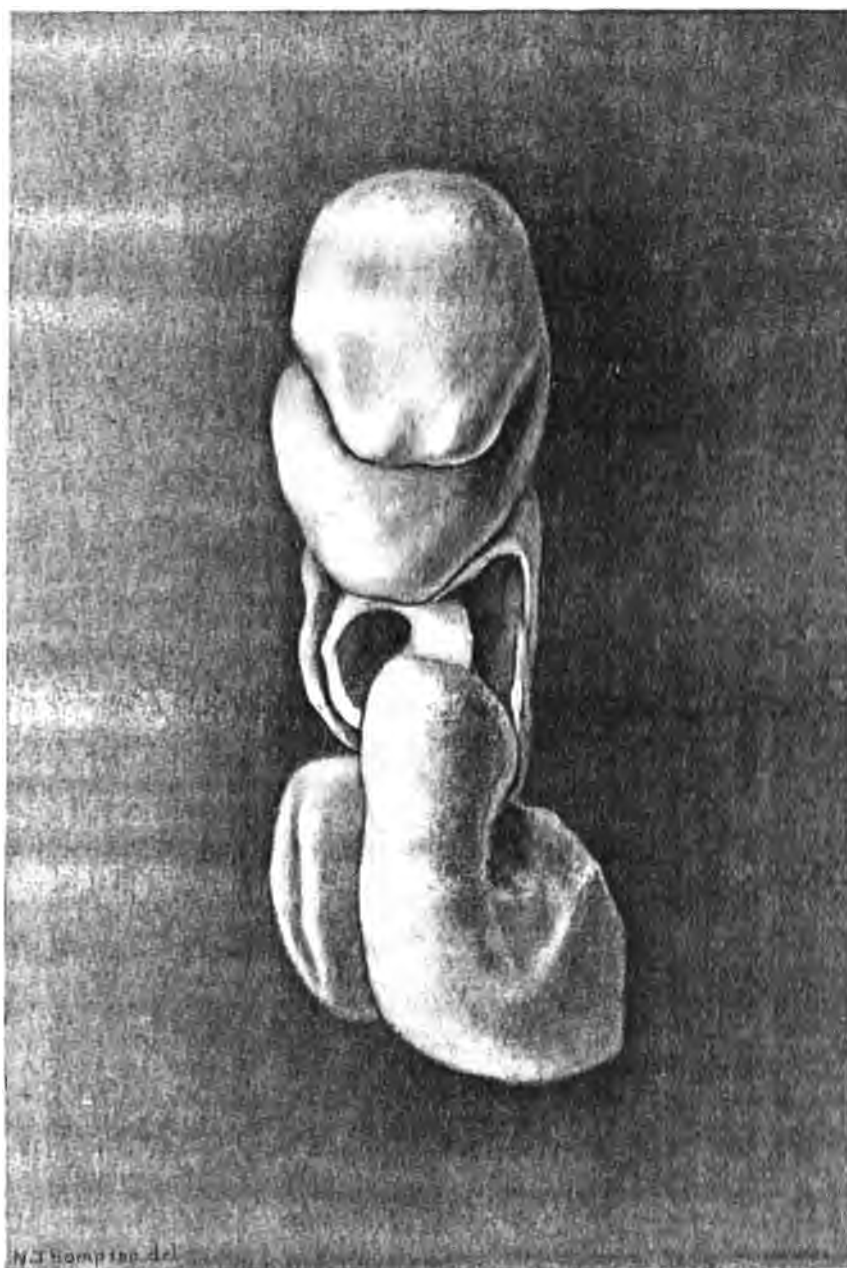
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EXPLANATION OF PLATES.

Plate I. Drawing of a plaster cast of the reconstructed embryo, right side (nearly half size).

Plate II. Drawing of a plaster cast of the reconstructed embryo, frontal view (nearly half size).

Plate III. Graphic reconstruction of embryo from serial sections; the endothelial tube only of the heart is shown. *n.p.*, points to place of anterior neuropore; F.B., fore-brain; *o.v.*, optic vesicle; M.B., mid-brain; I.R., isthmus rhombencephali; i-vii, neuromeres of hind-brain H.B.; *t.g.*, trigeminal ganglion; *a.f.g.*, ganglion acoustico-facialis; *ot.*, otocyst; 1-23, somites; *b.m.*, remains of bucco-pharyngeal membrane; *m.t.*, median rudiment of thyroid body; *p.¹-p.⁴*, pouches of pharynx P.; *o.*, oesophagus; S., stomach; L., liver; *s.t.*, septum transversum; *am.*, root of amnion; V.D., vitelline duct; M.G., mid gut; N., notochord; H.G., hind gut; C., cloaca; *al.*, allantois; *c.m.*, cloacal membrane; T., tail; *m.g.*, medullary groove; R.A. and L.A., right and left auricles; *v.*, ventricle; A.C., auricular canal; A.S., aortic stem; B.C., bulbus cordis. (*Note.*—Neither the left horn of the sinus venosus nor the opening of the transverse piece into the right horn is indicated in the figure.)

THE FORM AND NATURE OF THE MUSCULAR CONNECTIONS
BETWEEN THE PRIMARY DIVISIONS OF THE VERTE-
BRATE HEART. By ARTHUR KEITH, M.D. (Aberd.), F.R.C.S.
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and MARTIN FLACK, B.A. (Oxon.), *Assistant Demonstrator of*
Physiology, London Hospital Medical College.

Introductory.—In a paper contributed to the *Lancet* some months ago (5), the writers confirmed and extended the discovery of Tawara (7), viz. that there is within the mammalian heart a system of peculiar musculature (the a.-v. system) which, beginning as a small root (the *Knoten*) in or near the base of the interauricular septum on the right side, eventually spreads out in an arborescent form beneath the endocardium of both ventricles, its final twigs becoming everywhere continuous with the ordinary musculature of the ventricles. It seemed to us essential to examine other regions of the heart for such peculiar musculature. Moreover Wenckebach (8) has demonstrated by exact clinical methods that a delay may occur in the conduction of the cardiac impulse from sinus to auricle. This fact stimulated us to investigate fully the nature of the muscular connection between the sinus and the auricle, which has already been partly described by Wenckebach in the human heart.

In this paper therefore the writers propose to deal with the results of an extended inquiry, made with three objects in view:—

I. To ascertain the extent, nature, and position of the muscular connection or connections between the primary divisions of the heart in all classes of the vertebrate kingdom.

II. To seek in the sinus, auricle, and bulbus cordis for a differentiation in form and structure of a system of muscle fibres corresponding to that now known to exist in the ventricle: in short, to ascertain whether the musculature in which the heart-impulse is held to arise, and by which it is conducted, differs in form and structure from that which is mainly contractile in nature.

III. To trace the evolution of the a.-v. muscular system, as found in the human heart, from the simpler and more definite form seen in the heart of fishes.

Material.—It is important that those who may consult this paper

should know the exact material used by us in this inquiry, and its method of preparation. In the appended list of material we do not include the numerous hearts which have been dissected by knife and forceps, but only those which have been examined by a series of microscopic sections.

List of Material.

Fishes.—Eel, dog-fish, salmon.

Amphibia.—Frogs (3).

Reptilia.—Lizard (species unknown), tortoise, turtle.

Birds.—Sparrows (2), goldfinch.

Mammals (other than human).—Mole, porpoise, dolphin, kangaroo, wallaby, whale (*B. musculus*), mouse, shrew-mouse, rat (2), kitten (2), ram, pig, cart-horse, pony, fetal gibbon.

Human.—Embryos (2), normal hearts, malformed hearts, and fifteen hearts having definite pathological lesions.

Method of Preparation.—For macroscopic specimens for dissection a modification of Kaiserling's method was used. The great advantage of this method is that the natural colour of the muscle fibres returns after fixation, thereby rendering easier the dissection of the different systems of muscle fibres. The procedure is as follows:—

(1) The heart must be well washed in running water for 12 hours prior to fixation, and the cavities stuffed with tow or cotton-wool.

(2) The specimen is then fixed in the following solution:

Formalin, 200 c.c.

Water, 1000 c.c.

Potassium nitrate, 15 grams.

Potassium acetate, 30 grams.

In this solution it remains at least 24 hours, and longer if it be large, hard, or tough.

(3) Specimen placed in 80 per cent. spirit until its colour returns.

(4) Kept in equal parts of glycerine and water.

In the preparation of microscopic specimens stages (3) and (4) are omitted. After (2) the specimen, or the desired parts of it, is well washed in running water. It is then transferred to spirit (24 hours), next alcohol in stages from 70–100 per cent. for 24–48 hours, then in xylol until clear, and finally embedded in paraffin. We have found that the process of embedding is much facilitated by exhausting the incubator. By this means clear, firm blocks with no trace of air-bubbles are obtained. The blocks were cut in

the main at $10\ \mu$, except when it was desired to study the minutest structure of the specimen, when they were cut from $4\ \mu$ to $7\ \mu$ in thickness, according as the nature of the tissue permitted. The sections were stained by Ehrlich's acid hæmatoxylin and Van Gieson's stain, dehydrated, and mounted in Canada balsam. It is important to overstain with hæmatoxylin, otherwise the nuclei will not be well seen, owing to the decolorising action of the second stain.

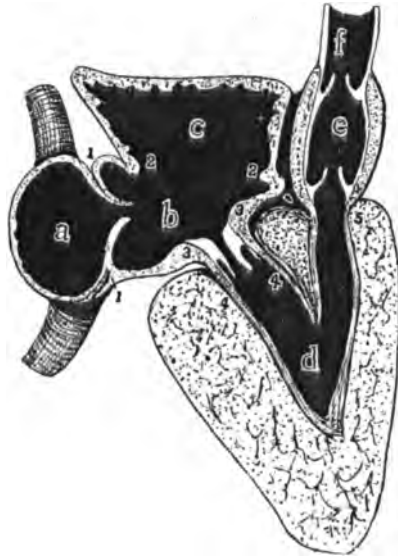


FIG. 1.—Diagram of a generalised type of vertebrate heart—combining features found in the eel, dog-fish, and frog—showing the primary cardiac chambers and their lines of union.

a, sinus venosus and veins; b, auricular canal; c, auricle; d, ventricle; e, bulbous cordis; f, aorta; 1-1, sino-canal junction and venous valves; 2-2, canal-auricular junction; 3-3, annular part of auricle, containing special muscle fibres; 4-4, invaginated part of auricle; 5, bulbo-ventricular junction. By the longitudinal fibres lining the ventricle there is a connection between the annular fibres of the auricle and the bulbous musculature.

Literature.—With regard to literature, we have been unable to find any previous paper approaching the nature of our research. The writings of Gaskell (2), MacWilliam (6), and Engelmann (1) have proved of great service. We accept the teaching (1) that the heart's impulse is conducted by the cardiac muscle tissue, (2) that normally the impulse arises in the musculature of the sinus, setting the heart's rhythm, and then passes to the auricle and ventricle, finally reaching the bulbous cordis.

The Primary Divisions of the Vertebrate Heart.—Before proceeding to describe the muscular connections between the primary divisions of the heart, it is necessary for us to define exactly what we regard as such.

They are well seen in the generalised diagram (fig. 1). There are five primary divisions of the heart:—

- (1) The sinus venosus (*a*).
- (2) The auricular canal (*b*).
- (3) The auricle (*c*).
- (4) The ventricle (*d*).
- (5) The bulbus cordis (*e*).

There are four junctional lines:—

- (1) *The Sino-canal*, marked by the venous valves, the free margin of the valves forming the boundary-line between the cavity of the sinus and the cavity of the auricular canal (1-1 in fig. 1).

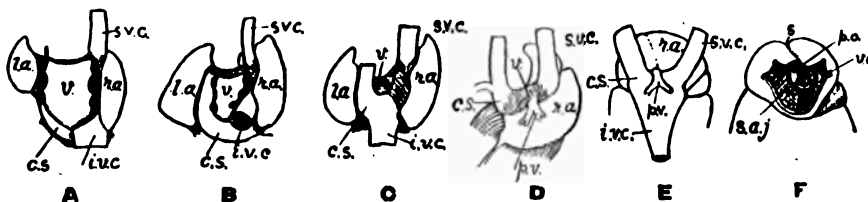


FIG. 2.—Series of diagrams to illustrate the parts in the human heart corresponding to the parts of the primitive heart.

A, dorsal view of auricular part of the human heart; B, corresponding view of wallaby's heart; C, corresponding view of the heart of a child in which the lungs were fused and the vestibule of the left auricle consequently unexpanded; D, corresponding view of the heart of a malformed fetus in which the inferior vena cava was absent; E, corresponding view of the heart of the frog (Gaupp); F, corresponding view of the heart of the frog, the interior of the sinus venosus being exposed to show that the pulmonary veins open within the sino-auricular junction. In this figure, *p.o.*, orifice of pulmonary veins; *v.o.*, orifice of sinus venosus; *s*, attachment of interauricular septum; *s.a.j.*, sino-auricular junction. *v.*, vestibule; *r.a.*, right auricle; *l.a.*, left auricle; *s.v.c.*, superior vena cava; *c.s.*, coronary sinus; *i.v.c.*, inferior vena cava.

- (2) *The Canalo-auricular*, marked by a thickening of the musculature round the ostium of the auricle, situated on the dorso-lateral wall of the auricular canal (2-2 in fig. 1).

- (3) *The Canalo-ventricular*, marked in the mammalian heart by the auriculo-ventricular valves, the free margins of which separate the cavity of the auricular canal from that of the ventricle (4-4 in fig. 1).

- (4) *The Bulbo-ventricular*, situated at the junction of the ventricle and bulbus (5 in fig. 1).

The Primary Divisions and Junctional Lines in the Mammalian Heart.
—Our knowledge of the heart has been derived in great part from experiments made on the simpler hearts of the eel, frog, and turtle; in order to transfer accurately that knowledge to the mammalian, and more especially to the human heart, it is necessary to identify in them the primary divisions which are seen so clearly in the simpler hearts. We propose, therefore,

in the first place, to identify the five primary divisions above mentioned in the human heart.

The Sinus Venosus of the Human Heart.—In fig. 2 is shown a series of illustrations of views of the sinus venosus in various hearts; the view represents the venous or auricular end of the heart, looked at from the dorsal side. The sinus (see E) is formed by the union of three great vessels—the right duct of Cuvier (*rt. sup. v.c.*), the left duct of Cuvier (*lft. sup. v.c.*), and the inferior vena cava (the hepatic vein of fishes). In the human and in the mammalian heart, the musculature of the auricular canal has grown over and submerged the greater part of the sinus (*o*, fig. 3); two parts only are left exposed on the surface of the heart—(1) the musculature of the superior vena cava, (2) the musculature of the coronary sinus (the representative of the left superior vena cava (see figs. A, B, C). But if a section be made across the line at which the sinus becomes submerged (the stria terminalis of His), a second or deep stratum of musculature is seen (beneath *o*, fig. 3); this probably belongs to the sinus venosus, since it extends beneath the endocardium of the auricle, from the position of one venous valve to that of the other. Besides these three definite remnants of the sinus musculature, there is also the musculature—or part of it—in the Thebesian and Eustachian valves, these being remnants of the right venous valve. There is often also to be found a thin muscular layer along the lower border of the fossa ovalis; it occupies the position of the left venous valve, and is probably derived from it. Thus, the chief remnants of the sinus venosus have to be sought for in the right auricle of the human heart. Its musculature is represented by:—

- (1) The termination of the superior vena cava.
- (2) The coronary sinus.
- (3) The submerged stratum.
- (4) The remnants of the venous valves.

It may be, however, that there are also remnants of the sinus in the left auricle of the human heart. In fig. 2, F, it is seen that in the heart of the frog the musculature of the sinus at the sino-auricular junction (*s.a.j.*) includes within it the orifice of the pulmonary veins. This is also seen in the heart of the malformed fetus, fig. 2, D. It is possible, therefore, that, as the part of the auricular canal (*v.*) which is to become the vestibule of the left auricle expands, a part of this sinus musculature is also involved in the process, and may persist in the left auricle of the human heart around the orifices of the pulmonary veins.

In a part or in all of this sinus musculature the heart rhythm is believed to be initiated.

The Auricular Canal of the Human Heart.—In the simplest form of heart the auricular canal, which joins the sinus venosus to the ventricle, is differentiated into three parts (see fig. 1)—(i.) a basal part (opposite the auricle), (ii.) an annular part (3-3), (iii.) an invaginated or intraventricular part (4-4). The invaginated part forms an isolated layer beneath the auriculo-ventricular valves, its musculature becoming continuous with that of the ventricles near the apices of the valves (fig. 1). Only a small part of this musculature remains in the human heart; it forms the a.-v. bundle. This we shall treat of more fully later on. The annular part of the canal—the “auricular ring,” as we shall term it in this article—has in the human heart become submerged in the auriculo-ventricular groove just above the

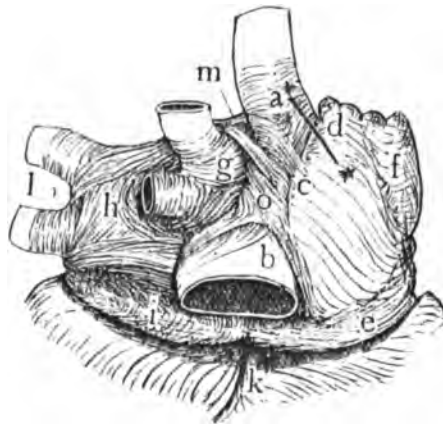


FIG. 3.—The auricular part of the human heart from behind, showing the musculature of the termination of the great veins.

a, superior vena cava surrounded by musculature derived from the sinus; *b*, inferior vena cava; *c*, to the right of the sulcus terminalis, above *c*, sinus fibres cross the sulcus to join auricle proper; *d*, at sino-auricular junction, where peculiar musculature is found most abundantly; *e*, annular fibres of auricle; *f*, appendix; *g*, fibres passing from interauricular septum to vestibule of left auricle between the two left pulmonary veins; *h*, vestibule; *i*, coronary sinus, showing continuity of fibres with right and left auricles; *j*, base of ventricles at interventricular sulcus; *k*, left pulmonary veins; *l*, constant band passing from sinus musculature to vestibule of left auricle; *m*, muscle of auricular canal submerging sinus; *n* represent line of section of fig. 6, A.

base of the auriculo-ventricular valves (*c*, fig. 3). Only one essential change has taken place. This can best be clearly explained by the help of a figure.

In the reptilian as in the amphibian heart (fig. 4, B) the annular part forms a simple ring; the interauricular septum lies within it, separating the right from the left a.-v. orifice. But in the mammalian heart the simple annular form has been lost; owing to the extension of the bases of the ventricles backwards under the basal wall of the auricular canal, the annular part has been folded as shown in fig. 4, A, so that the mesial folded part has now come to rest upon the upper or auricular margin of

the interventricular septum. From this supraventricular fold of the annular ring begins the a.-v. bundle (stippled in fig. 4, A).

The basal part of the auricular canal is best defined by explaining its origin. The auricle or auricles are outgrowths from the dorsal wall of the auricular canal (see fig. 1); the ventral wall remains unspecialised as the basal part. The basal part, it will be seen, is continuous with the sinus venosus, with the ostium of the auricle, and with the auricular ring. From a physiological point of view the basal part of the auricular canal is most important, since both Gaskell and MacWilliam found that it was a path of conduction from the sinus to the ventricle, so that a sino-ventricular rhythm could occur. It is therefore interesting to see whether the possi-

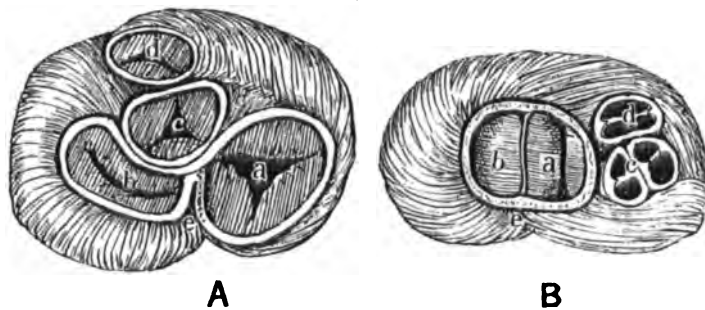


FIG. 4.—To illustrate the infolding and modification of the auricular ring in the mammalian heart.

A, base of the ventricles of human heart; B, base of the ventricles of heart of turtle. a, right auriculo-ventricular orifice; b, left auriculo-ventricular orifice; c, orifice of pulmonary artery; d, orifice of aorta; e, posterior part of the auricular ring, which becomes infolded in the mammalian heart. The stippled part near e represents the only part which remains undifferentiated in the mammalian heart.

bility of this rhythm remains in the mammalian heart. In the human, as in the mammalian heart, the basal wall has become profoundly modified by two great cardiac transformations which have occurred with the evolution of the pulmonary system. These changes are: (1) the formation of an interauricular septum, (2) the formation of a vestibule to the left auricle (figs. 2 and 3). The basal wall has supplied a large part, if not the whole, of these two structures. As the fibres of the lowest part of the interauricular septum come into intimate relation with the annular ring, it will be seen that it is therefore possible for a sino-ventricular rhythm to occur in the human heart. Indeed, a layer of longitudinal muscle fibres passes directly from the superior vena cava into the auricular septum, and thus reaches the musculature from which the a.-v. bundle commences. The musculature of the three parts of the auricular canal is represented in the human heart thus:—

(1) The basal part by the interauricular septum and by the vestibule of the left auricle.

(2) The annular part by the circular fibres surrounding the ostia above the bases of the auriculo-ventricular valves. The annular fibres also descend for some distance on the septal cusp of the tricuspid valve.

(3) The invaginated part by the a.-v. bundle.

The Auricles of the Human Heart.—In the fish's heart, the common auricle forms a well-demarcated outgrowth on the dorsal wall of the auricular canal. The ostium, by which it opens on the canal, is surrounded and indicated by a thick circular ring of musculature (fig. 1, 2-2). In the mammalian heart, the development of the interauricular septum and of the vestibule of the left auricle from the basal wall has led to a division of the auricle and to a wide separation of its two parts (see fig. 3). However, in the mammalian, and especially in the human heart, a prominent ridge of musculature, commencing in the right auricle immediately in front of the termination of the superior vena cava and seen on the roof of the left auricle, still unites the two auricles, and represents the original continuity of the two chambers (see fig. 7, A).

Thus in the right auricle of the human heart there is musculature derived from three sources—(1) from the auricle proper, (2) from the auricular canal, (3) from the sinus venosus. In the left auricle the musculature arises from (1) auricle proper and (2) auricular canal. All these parts are in the freest muscular continuity.

The Ventricle of the Human Heart.—It is unnecessary in this place to discuss the correspondence of the common ventricle of the lower forms with the divided ventricular chamber of the higher forms. They are developed as outgrowths from the ventricular segment of the primitive cardiac tube; the part which remains undisturbed between the outgrowths forms the interventricular septum. The upper margin of the septum represents the least disturbed part of the lumen of the primitive tube; on it lies the a.-v. bundle.

The Bulbus Cordis of the Human Heart.—This fifth division of the heart is well marked in the primitive forms (fig. 1, c). It is generally supposed to be absent in the mammalian heart, but recently Greil (3) and one of the authors (4) has shown that this is not so; the infundibulum of the right ventricle represents practically the whole of this cavity. The musculature of the bulbus has become replaced entirely or for the greater part by that of the ventricle.

The Musculature of the Sinus Venosus and of the Sino-auricular Junction.—Having thus sketched out, perhaps too briefly, the primary divisions of the heart, we now propose to describe the musculature of the

sinus venosus and its connections with the other parts of the heart, more particularly in relationship to two points in physiology. (1) The rhythm of the heart begins in the sinus: does its musculature or any part of its musculature show any peculiar differentiation in connection with this function? (2) What are the muscular connections of the sinus; are they restricted so that a sino-canalar or sino-auricular "block" may occur, as is supposed by Wenckebach, or are they so wide and diffuse that such a block is inconceivable from an anatomical point of view? These two matters we shall discuss in relationship to the human heart, using our

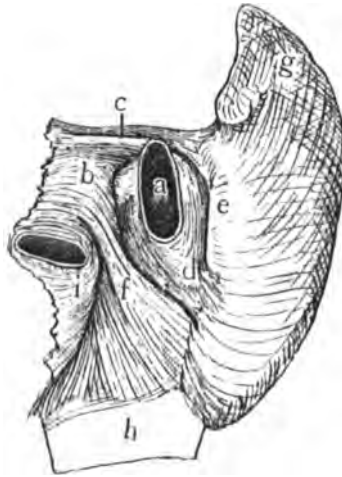


FIG. 5.—Right auricle of human heart viewed from above, to show connections of musculature at the termination of the superior vena cava.

a, superior vena cava cut across; b, vestibule of left auricle; fibres are seen to enter the interauricular septum from the superior vena cava; c, sinus musculature of superior vena cava passing to left auricle (*m* in fig. 3); d, sinus musculature of superior vena cava crossing sulcus terminalis to right auricle; e, sino-auricular junction; f, musculature of interauricular septum submerging sinus; g, appendix; h, inferior vena cava; i, septal fibres passing on to vestibule of left auricle below orifice of pulmonary vein.

comparative material only in so far as it throws light on the questions we discuss.

Taking the latter question first, we may say at once that the musculature of the sinus is freely continuous with that of the auricular canal and of the auricle. An impulse arising in the sinus musculature around the termination of the superior vena cava (fig. 3, *a*) may spread directly (1) into the musculature of the interauricular septum, and thus to the network in which the a.-v. bundle begins (fig. 5, *b*); (2) to the vestibule of the left auricle (*m*, fig. 3), and to the auricle proper along the interauricular bridge (fig. 5, *c*); (3) to the auricular canal of the right auricle; (4) to the right auricle proper (fig. 5, *d*). If the impulse commences in

the coronary sinus, then it may spread directly (1) to the vestibule of the left auricle; (2) to the annular fibres of the left auricle; (3) to the annular fibres of the right auricle (fig. 3, *i*). Indeed, the higher one ascends in the vertebrate scale, the less becomes the amount of the sinus musculature, but the greater the closeness of its connection with the canalar and with the auricular musculature. It therefore appears to us that the sino-auricular "block" cannot be due to an anatomical lesion of a narrow bridge of fibres, but must arise from the depression, probably of vagal origin, of the muscular tissue in this region.

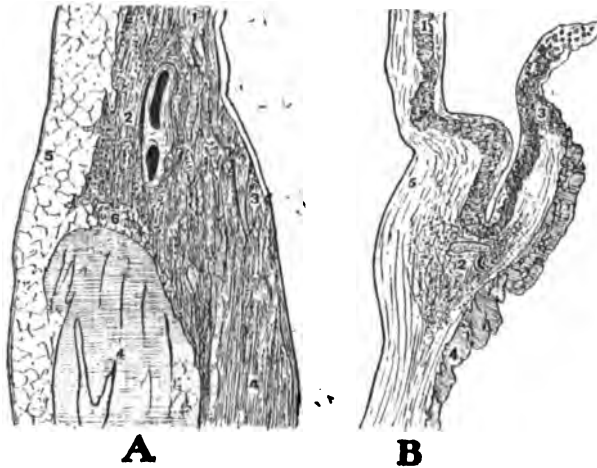


FIG. 6.—A, sino-auricular junction in human heart (position indicated in fig. 3); B, sino-auricular junction in turtle's heart. The figures represent corresponding parts in the two hearts.

- 1, musculature of superior vena cava or sinus in A; of sinus venosus in B; 2, artery and surrounding musculature at sino-auricular junction; 3, position of venous valve in A. In B, 3 indicates junction of musculature of sinus and auricle in the venous valve; 4, auricular muscle, differs from sinus musculature in both A and B in having a very slight endocardial covering; 5, sub-epicardial tissue; 6, connective tissue between sinus and auricle.

In fig. 6 we give two sections of the sino-auricular junction:¹ A is that of the human heart made across the sulcus terminalis in the position shown in fig. 3, B that of the heart of the turtle. The venous valve (see fig. 6, B) at the sino-auricular junction is seen to be really a fold of the cardiac tube: the musculature of one side of the valve is derived from the

¹ We use the term "sino-auricular" in preference to "sino-canalar" because, although a true sino-canalar junction exists on the dorsal side in the most primitive hearts (see fig. 1), yet in all but these the part of the canal between the sinus and the auricle disappears, and the dorsal junction becomes really a sino-auricular junction. Moreover, as the term "auricle" is usually applied in the mammalian heart to the parts representing both auricular, canal and auricle proper, the term "sino-auricular" is the more appropriate.

sinus—that of the other is continuous with the auricular musculature. At the free margin of the valve the sino-auricular muscle is continuous (fig. 6, B, 3). A certain amount of fibrous tissue belonging to the epicardium is enclosed within the folds of the valve; in this an artery is frequently present. By the musculature of the valves an impulse may be freely distributed in the musculature of the auricular canal and of the auricle proper, for at the upper and lower angles at which the valves unite their musculature spreads out and joins freely with that of the auricular division of the heart (fig. 6, B, 4). In the mammalian heart a distinct remnant of the sino-auricular junction, so well shown in more primitive hearts, can be

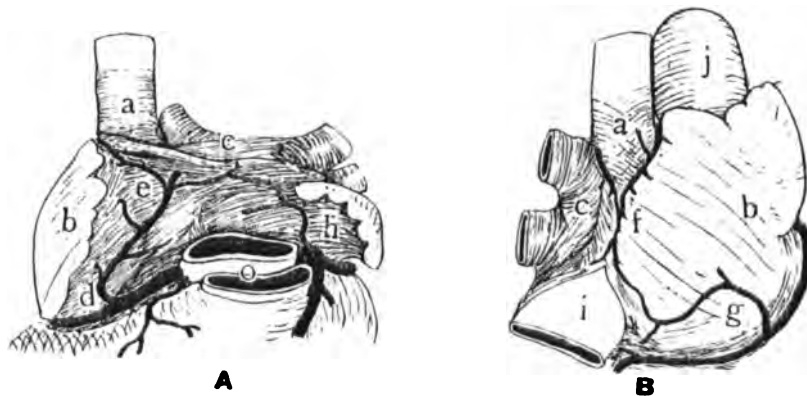


FIG. 7.—Showing blood-supply of the musculature of the sino-auricular junction.

A, aorta and pulmonary arteries removed, exposing auricles from the front; B, right auricle from the side. *a*, superior vena cava; *b*, appendix; *c*, vestibule of left auricle; *d*, artery arising from right coronary and passing to sino-auricular junction; at *e* the artery divides, one branch passing in the junction in front and the other in septum behind superior vena cava; *f*, union of two branches above mentioned in sulcus terminalis; *g*, anastomosing branch from right coronary artery; *h*, anastomosing branch from left coronary artery; *i*, inferior vena cava; *j*, aorta; *o*, aorta and pulmonary artery.

recognised (fig. 6, A). In the human heart, as in most mammalian hearts, an artery or arterial circle lies in the junction (fig. 6, A, 2); the artery is surrounded by fibrous tissue in which are numerous peculiar muscle fibres, some nerve cells and nerve fibres. The nerve cells and fibres we find from dissection to connect with the vagal and sympathetic nerve trunks which form so rich a plexus and exert so powerful an effect at this junction. The musculature of the superior vena cava becomes continuous with that of the auricle and of the auricular canal both on the outer and inner side of the artery.

Our search for a well-differentiated system of fibres within the sinus, which might serve as a basis for the inception of the cardiac rhythm, has led us to attach importance to this peculiar musculature surrounding the

artery at the sino-auricular junction (fig. 6, A, 2). In the human heart the fibres are striated, fusiform, with well-marked elongated nuclei, plexiform in arrangement, and embedded in densely packed connective tissue—in fact, of closely similar structure to the Knoten. The amount of this musculature varies, depending upon how much of the sinus has remained of the primitive type: but in the neighbourhood of the tania terminalis there is always some of this primitive tissue found. Macroscopically, the fibres resemble those of the a.-v. bundle in being paler than the surrounding musculature, *i.e.* in being of the white variety. They can be dissected out on the superior vena cava in the region corresponding to the right venous valve (*a*, fig. 3), and at the coronary sinus in the interval between it and the inferior vena cava and left auricle (*b*, *i*, fig. 3). Another remarkable point in connection with these fibres is the special arterial supply with which they are provided (fig. 7, A and B). These arterial branches, as noticed by Wennebach, embrace the sino-auricular junction. It will be seen that they come from both right and left coronary arteries and form what may be termed the “sino-auricular arterial circle.” We might mention also that, in some of the pathological hearts cut by us, sections of this region appeared to show a definite increase in the amount of fibrous tissue present—a fact of considerable importance, since we have found that the fibrous tissue of the Knoten and a.-v. bundle is sometimes increased in pathological hearts.

The nature of this remnant is perhaps best exemplified in the heart of the mole (fig. 8). Here it is seen that at the sino-auricular junction (A, E) there is a mass of remarkable tissue. It appears to the eye as a very intimate network of palely stained undifferentiated fibres with a large number of well-stained nuclei. It is totally different from the surrounding musculature, and contains but little fibrous tissue. Although the mass by its connections is undoubtedly muscular, the nerves in the neighbourhood of the superior vena cava appear to come into very intimate connection with it, so much so that we feel justified in stating that a highly differentiated neuro-muscular junction occurs at this point. In this heart also the bundle (1, fig. 8) is of absolutely identical structure.

In a section of the heart of the wallaby in this region there is seen under the low power (2'') a mass of fibrous tissue apparently separating superior vena cava from auricle. On closer inspection, however, it is seen that very delicate, palely stained, primitive muscular tissue is enclosed within the fibrous mass.

A section of this junction in the porpoise's heart is interesting. The musculature of the superior vena cava has largely remained primitive in type. The wall of the superior cava consists of alternate layers of fibrous tissue and primitive palely staining fibres. Just at the junction, however,

of the superior vena cava and auricle, a network of these fibres and fibrous tissue is formed. In it there is an artery, and two nerve trunks lie close by.

In the dolphin's heart, on the other hand, there is no difference between the greater part of the musculature of the superior vena cava and that of the auricle. But in the region of the *tænia terminalis* there occurs some loosely-woven fibrous tissue, in the meshes of which are contained an artery and wavy, delicate muscle fibres with well-marked nuclei.

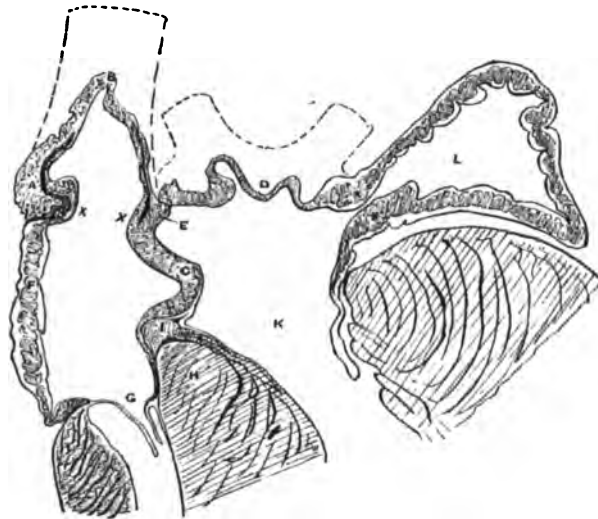


Fig. 8.—Coronal section of the mole's heart, showing position of musculature at sino-auricular junction.

xx, junction of superior vena cava and right auricle; A, peculiar musculature described in paper at sino-auricular junction; B, section of wall of superior vena cava; the position of the superior vena cava is outlined; C, interauricular septum; D, vestibule of left auricle; the pulmonary veins are outlined; E, similar musculature to A lying at junction of superior vena cava and vestibule; F, wall of right auricle; G, right auriculo-ventricular orifice; H, interventricular septum; I, a.-v. bundle similar in structure to A; K, left auriculo-ventricular orifice; L, left auricle **; canalo-auricular junction.

The ram's heart also shows a similar characteristic set of fibres in this region. The tissue in this case shows a marked amount of fibrous tissue loosely interwoven with palely-staining fibres closely resembling those of the sinus of the frog. The remnant also occurs in the hearts of the kitten, rat, and mouse.

From the above it will be seen that the presence of these primitive fibres is remarkably constant. Physiological experiments have clearly demonstrated that normally the heart's rhythm begins in the neighbourhood of the great veins, and that here nervous influence has a most potent effect (MacWilliam, Engelmann, Hering, and others). The fact, therefore,

that there is a constant differentiation of certain fibres in this region, which, moreover, are in close connection with the nerves affecting the heart's rhythm, leads us to attach great importance to these fibres, and we feel justified in expressing the opinion that it is in them that the dominating rhythm of the heart normally begins.

The Canalo-auricular Junction.—At the ostium of the auricle in the lower hearts the musculature is directly continuous with that of the auricular canal (fig. 1, 2-2). In them there is a difference in the type of fibre constituting the two parts, those of the auricle being coarser, more striated, and more deeply stained. In the mammalian heart the junction between the parts representing the auricular canal and the auricle proper is also marked by a thickening of the musculature. The fusion of the different systems of muscle fibres, however, is for the most part so intimate that it is difficult to distinguish between them. We could find no trace of any especially differentiated fibres at this junction.

The Canalo-ventricular Junction.—This is the junction of the auricular canal with the ventricle. It has been described by MacWilliam in the heart of the eel. In this heart the auricular ring is connected to the ventricular system by the fibres of the invaginated part of the auricular canal (see 4-4, fig. 1). This part of the canal shows a differentiation even in the eel. Its fibres differ from those of the rest of the canal in being larger, less striated, staining more palely, and possessing a very large distinct nucleus.

In the frog there is a similar connection all round the auriculo-ventricular orifice below the base of the a.-v. valves, but particularly below the auricular septum. The fibres of the connection are not differentiated from those of the rest of the canal: they are shut off by fibrous tissue from the ventricular system in the upper part of their course, but later on they fuse with the fibres of the innermost part of the ventricular wall. The canalo-ventricular junction in the reptilian heart is similar to that of the fish and of the frog.

In the mammalian heart the auricular ring and the invaginated fibres become profoundly modified. Taking the human heart as a type, we find that the ring can still be traced round the right auriculo-ventricular orifice above the bases of the valves. The fibres are no longer isolated, but can be identified by their structure. No trace of them can be found in the canal of the left auricle. It will perhaps be well to recall the arrangement of the muscular connection between the auricular canal and the ventricle in the human heart. The system begins in the "Knoten," a small mass of interwoven fibres in the central fibrous body of the heart, having slender connections with (1) the musculature of the interauricular septum; (2) the

circular fibres of the right auricular canal. From this arises the main bundle which passes along the upper border of the interventricular septum below the pars membranacea septi. Here it divides into a right and a left division, which pursue a subendocardial course in the right and left ventricles respectively, and finally fuse with the ventricular muscle. The fibres composing the main bundle, and more especially its arborisations, vary very much in type in the hearts of different species. In some hearts there is a marked difference from the ordinary ventricular musculature. Such is the case in the hearts of the sheep, ox, calf, cart-horse, pony. In these the main bundle consists of long, delicately striated fibres, with large nuclei. The end arborisations consist of fibres belonging to the Purkinje system. In other hearts the fibres of the bundle and its terminal branches are not so well differentiated from the ventricular fibres. This is the case in the whale, kangaroo, wallaby, dolphin, man, rat, kitten, mouse, shrew-mouse, and pig. In these hearts, however, and especially in the first four mentioned, there is still a differentiation of fibre rendering the bundle quite distinct from the ordinary ventricular musculature. The fibres of the bundle are larger, more delicate, less striated, and stain less deeply than those of the ventricle proper. In certain other hearts, namely, those of birds, the authors have been unable to find any differentiation of fibres in the bundle; the guides to it being its position and its definite demarcation by fibrous tissue. In the birds' hearts examined by us, the a.-v. bundle arises from the auricular ring and dives at once into the interventricular septum.

The a.-v. bundle is the sole muscular connection between the auricular canal and the ventricle; there is no direct connection between auricle proper and ventricle in the mammalian heart. It must be admitted, however, that in one case, namely, in the heart of a rat, the auricular and ventricular fibres appear to come into close apposition in the right lateral auriculo-ventricular region, and undoubtedly represent one of the connections described by Stanley Kent. In the heart of the sparrow also there is a similar close apposition of fibres in this region. This close apposition, however, cannot be looked upon as a connection; the a.-v. bundle is to be regarded as the sole connection between the auricular canal and the ventricle.

The Bulbo-ventricular Junction.—This junction is well marked in the primitive hearts (see 5, fig. 1). In all a circular groove containing epicardium separates the ventricular from the bulbar musculature, but not completely; the inner or subendocardial layer of ventricular musculature becomes continuous with the bulbar musculature. In the frog's heart this is also the form of connection, but the union is three or four times denser on the dorsal than on the ventral side of the b.-v. junction.

In the mammalian heart the bulbus has become fused with the right ventricle, forming the infundibulum of that cavity. Greil's research on the heart led him to the conclusion that, although the cavity of the bulbus remains, its musculature has been overgrown and replaced by that of the ventricle. The moderator band which passes from the septal wall of the right ventricle to the base of the anterior group of muscoli papillares marks the separation of the bulbar part from the rest of the right ventricle. On this band of muscle the right division of the a.-v. bundle descends: that is, if our identification be correct, the right septal division descends in the position of the bulbo-ventricular junction. There can be no doubt, at least, that there is no bulbo-ventricular separation of fibres in the mammalian heart.

The Morphology of the A.-V. Bundle.—This is the third point which we had in mind during this research. As the result of our examination of the hearts in different branches of the vertebrate kingdom, we have come to the following conclusions in reference to the morphology of this bundle:—(1) The "Knoten" represents the only part of the annular ring of the auricular canal of the primitive heart which has remained undifferentiated in type. The rest of the ring has become differentiated and is imbedded in the other auricular musculature as explained above. (2) The main bundle and its two divisions represent the remnant of the invaginated portion of the auricular canal.

The chief evidence in favour of (1) may be summarised thus:—The different position occupied by the Knoten in relation to the central fibrous body in the hearts of different animals, *e.g.* of the sheep, horse, and man, points to the fact that in each a different portion of the auricular ring has remained undifferentiated as the Knoten. The musculature of the Knoten resembles in structure the other portion of the primitive canal which has remained undifferentiated, namely, the remnant at the sino-auricular junction, evidenced especially by the hearts of the mole, rat, and ram. Lastly, in the heart of a human embryo (32 mm. long) the auricular ring is clearly seen, and the part which is to persist as the Knoten is in close continuity with the ventricular musculature. The ring in this embryo is at the upper part of the interventricular septum, and its fibres are of exactly the same type as persist in the Knoten throughout life.

The evidence that the main bundle is the remnant of the invaginated portion of the auricular ring reveals itself as we proceed from the lower to the higher forms. In the eel this part of the auricular canal forms the a.-v. connection, which is all round the auriculo-ventricular orifice. In the amphibian and reptilian heart the connection is still around the whole orifice, but it is thickest at the base of the interauricular septum. In the

bird's heart the connection is comparatively large, and is situated solely at the base of the interauricular septum. In the mammalian heart the connection is small, and occupies the upper border of the interventricular septum. It is beyond the purpose of this article to discuss the physiological reason for this restriction of the muscular connection between the auricle and the ventricle to a narrow bundle which measures on the average only $1.5 \times .8$ mm. in diameter; but its persistence in the position which it occupies becomes intelligible when it is called to mind that the upper border of the interventricular septum represents the least-disturbed part of the lumen of the embryonic cardiac tube.

SUMMARY.

- I. (a) The muscular connection in the lower hearts between sinus and auricular canal, and in the higher between the parts of the heart representing them, is intimate. In the latter, fibres pass directly from this junction to the vicinity of the a.-v. bundle.
- (b) The canalo-auricular junction is marked by a thickening of the heart wall at this point. The muscular connection is diffuse. In the lower forms there is a difference between the fibres of the two parts, but in higher forms the fusion is so intimate that no difference in the type of fibre can be distinguished.
- (c) The canalo-ventricular junction decreases in extent from the lower to the higher forms; in the latter it is represented solely by the a.-v. bundle.
- (d) The bulbo-ventricular junction is well marked in the lower hearts. In higher forms the ventricular musculature has replaced that of the bulbus.
- II. (a) There is a remarkable remnant of primitive fibres persisting at the sino-auricular junction in all the mammalian hearts examined. These fibres are in close connection with the vagus and sympathetic nerves, and have a special arterial supply; in them the dominating rhythm of the heart is believed to normally arise.
- (b) No special differentiation of fibres was found at the canalo-auricular and bulbo-ventricular junctions.
- III. (a) The Knoten is a part of the primitive auricular ring which has remained undifferentiated.
- (b) The main bundle and its branches represent the invaginated portion of the primitive auricular canal.

We wish to express our thanks to Mr Humphrey Neame, and particularly to Mr William Chesterman, for their help in the preparation of microscopic sections.

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Note.—Since the above was written, Dr J. Mackenzie has kindly drawn our attention to a recently published paper of Hering's, "Ueber die Automatie des Säugethierherzens," in *Pflüger's Archiv*, Bd. 116, p. 143. It is interesting to note that Hering brings about complete stoppage of the supraventricular parts of the heart by a cut made at the sino-auricular junction in precisely the same position as our section (fig. 6, A).

RARE ANOMALY OF THE HUMAN HEART—A THREE-CHAMBERED HEART IN AN ADULT AGED THIRTY-FIVE YEARS.

By Professor A. H. YOUNG, F.R.C.S., LL.D., *University of Manchester.*

I AM indebted to my friend and colleague, Professor J. Dixon Mann, for the opportunity of placing on record an abnormality of the human heart of such an unusual character that it may be regarded as being almost unique.

The specimen in question was the heart of a man aged 35 years, who during the greater part of his life appeared fairly healthy, and any malformation of the heart was not even suspected. Professor Dixon Mann has given me the chief facts of the clinical history of the case; and I learn that, when Professor Dixon Mann first saw the patient, in December 1905, he was propped up in bed, and presented the usual appearances of one suffering from chronic heart disease: he had a cough, with bronchial expectoration, the breathing was difficult, and there was some oedema about the ankles. The lips apparently were of the usual ruddy colour, the fingers were not clubbed, and, in short, there were no signs whatever of cyanosis. The area of cardiac dulness was considerably increased; the cardiac impulse was more extensive than normal, the apex beat being difficult to locate, the centre of the impulse was about the fifth interspace, just a little to the left of the middle line; there was no thrill. On auscultation, the first sound was found to be replaced by a loud, rushing systolic murmur, which extended over the whole cardiac area; no other murmur could be distinguished. Some amount of oedema was present at the base of the lungs. The liver dulness was slightly increased; there was no ascites.

No history of rheumatism was forthcoming, nor could any account of a definite commencement of the heart trouble be obtained.

The patient improved for a time; but later on a relapse occurred, he became cyanotic, and was admitted into the Salford Royal Hospital on the 28th of May 1906. He was then deeply cyanosed, and suffered greatly from dyspnoea; two days later he died. A post-mortem examination was made by Dr W. Mair, Pathologist to the Hospital, and Demonstrator of Pathology at the University of Manchester.

The heart, though enlarged in size, especially the ventricular part, seemed otherwise normal, and in particular the great emerging vessels

of the heart appeared to be quite normal as regards position. Dr Mair accordingly removed the heart in the usual manner, cutting the great vessels somewhat close to their origins: the ductus arteriosus was not retained in the removed heart.

Further examination of the heart showed that there was only a single functional ventricle. In this single ventricle there was hardly any trace of a division between right and left ventricles. In fact, the heart which was amphibian in type, closely resembled the heart of an ophidian reptile.

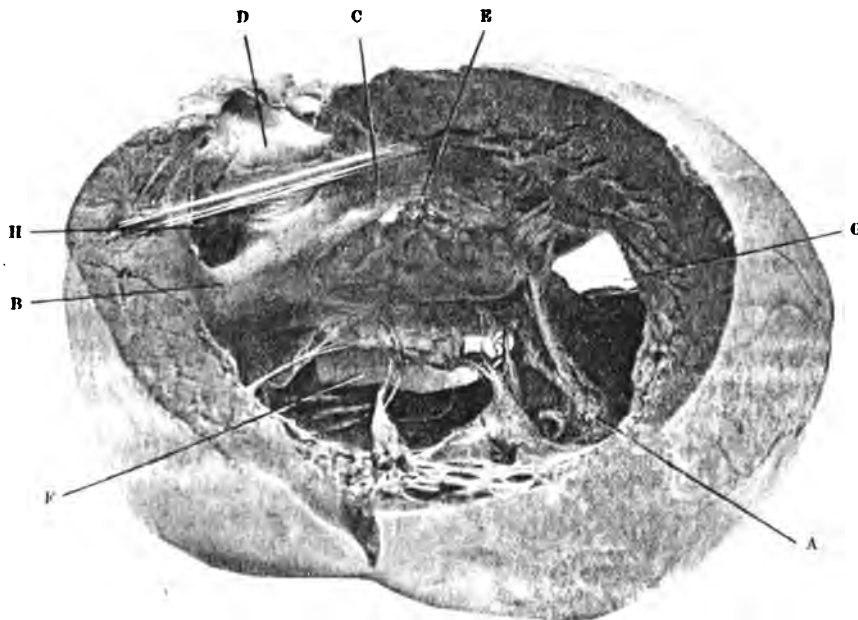


FIG. 1.—The cavity of the common ventricle (from a photograph by Messrs Flatters & Garnett, Manchester). Part of the anterior wall of the ventricle has been removed and the ventricle opened out laterally; a glass rod is inserted to keep the cavity open.

A, septum inferius; B, right infundibular band; C, left infundibular band; D, aorta; E, orifice of the pulmonary artery; F, right auriculo-ventricular aperture and tricuspid valve; G, left auriculo-ventricular aperture and mitral valve; H, remains of the bulbus cordis.

In the single ventricle, which was of large size, two more or less prominent ridges were distinguishable. One of these, the larger and the most prominent, was situated well to the right, on the posterior wall of the ventricle (fig. 1, B); the other ridge, smaller in size, and not so prominent, was situated about the middle, on the posterior wall of the ventricle (fig. 1, A). It extended from the level of the auriculo-ventricular apertures downwards, somewhat obliquely to the long axis of the ventricle,

to near the apex of the heart, and appeared to be little more than a well-developed "columnæ carneæ."

The two ridges are of considerable interest and of great importance, one apparently representing a rudimentary interventricular septum. At first one was inclined to regard the larger and more prominent ridge (B, fig. 1) as representing the septum; but subsequently it seemed clear that the septum was represented by the smaller and less prominent ridge (A, fig. 1).

The determination as to which of the two ridges really represented the interventricular septum did not in the least interfere with the existence of a single common ventricle, for neither of them was of sufficient size to constitute a division of the single ventricle into right and left ventricular chambers. Still, it modified considerably the view taken as to the essential nature of the common ventricle. If, *e.g.*, the more prominent and larger ridge, that to the right of the common ventricle, represented the interventricular septum, then a right ventricle was distinguishable as a small triangular fossa (fig. 1, H) immediately to the right of the ridge; it had no direct communication with the right auricle or with the pulmonary artery, but was continued upwards to form the root of the aorta.

To the left of the ridge now referred to, the whole remaining part of the common ventricle represented the left ventricle. This was of considerable size, and freely communicated with the so-called right ventricle—the two together forming a common ventricular chamber (fig. 1), receiving the separate apertures of the right and left auricles and giving off the origins of the aorta and the pulmonary artery. These latter vessels arose separately from the common ventricle, the aorta being in front and somewhat to the right, and the pulmonary artery behind and slightly to the left.

Each vessel was guarded by the usual semilunar valves, and in the pulmonary semilunar valve all the segments showed evidences of advanced atheromatous changes.

On external examination, the aorta and the pulmonary artery appeared to be in their usual relative positions, and it was not until the vessels were laid open that one suspected that they were transposed. On opening what from its position one thought was the pulmonary artery, it was seen that the two coronary arteries of the heart arose from the adjacent posterior sinuses of Valsalva of the presumed pulmonary artery; and for this reason I ventured to assert that the parent trunk was the aorta, and this was borne out by the relative thickness of its wall. The aorta and the pulmonary artery were transposed.

The auriculo-ventricular orifices were normal in size, and opened at the upper part of the common ventricle. The right auriculo-ventricular aperture

was guarded by the tricuspid valve (fig. 1, F), and the left aperture by the mitral valve (fig. 1, G); this latter, however, had a well-developed third segment, and was not unlike the tricuspid valve.

Of the two auricles it is only necessary to point out that the fossa ovalis was not entirely obliterated; a small slit-like aperture existed at its lower and anterior part.

Not being quite satisfied as to the real significance and nature of the two ridges above described, I was fortunate enough to meet my friend, Dr Arthur Keith, whose researches on the heart and its malformations are so well known; and we decided that the larger ridge—that situated to the right of the common ventricle—represented the right infundibular band, and that the real indication of the interventricular septum was the smaller and less prominent ridge (fig. 1, A) about the middle of the posterior wall of the common ventricle, and that it represented the septum inferius of His. This necessitated some modifications as to the different parts of the common ventricle as above described. The small triangular fossa referred to as representing the right ventricle must now be regarded as the remains of the bulbus cordis (fig. 1, H), whilst the large left ventricle previously described constitutes the whole of the true ventricular part of the heart, including both right and left ventricular chambers, just as though the “pars membranacea septi” were enormously enlarged and perforated, leaving the veriest traces of an interventricular septum.

These modifications, however, do not in the least alter the general conclusion one had arrived at as to the nature of the abnormal heart, which was, that the malformed heart is an example of transposition of the aorta and the pulmonary artery, together with almost complete absence of the interventricular septum, and with more or less absorption of the right ventricle into a single ventricle common to both right and left ventricles.

Professor G. D. Thane was good enough to give me a reference to a case of a similar nature in a child aged $4\frac{1}{2}$ years.¹ Other cases occurring in children are recorded by Dr Peacock.²

Dr Peacock³ refers to a case described by Tiedemann, 1808–10, of a boy who lived 11 years. In this case the heart was found to have two auricles and one ventricle, and from the latter cavity the aorta and pulmonary artery arose. The patient suffered from the usual symptoms of morbus ceruleus.

Similar malformations of the heart are not unfrequent in young

¹ Chiari, H., “Ueber ein Cor trilobulare (unioventriculare biatriatum) bei einem $4\frac{1}{2}$ jährigen Knaben,” *Centralblatt für die medicinischen Wissenschaften*, 1880, p. 186; also *Jahrbuch f. Kinderheilkunde*, xiv. p. 219; and the *Dublin Journal of Medical Science*, 1881, vol. lxxi. p. 384.

² *Malformations of the Human Heart*, London, 1866, 2nd edition, p. 21. ³ *Loc. cit.*

children, but it is not often that individuals possessing such malformation reach adult life.

Professor Dixon Mann observes that the literature of cardiac malformations reveals only a few instances in which the possessor of a "three-chambered heart" lived to adult life. The few cases recorded are therefore of much interest, and these I briefly mention.

Kreyzig¹ records a case by Wolf of a man who died at the age of 23 years, whose heart was found to contain two well-formed auricles and only one ventricle, from which two arteries took origin.

Witteke² found in the body of a man aged 24 years a heart with only one ventricle, with greatly thickened walls and without any interventricular septum. The vessels of the heart were in the normal position, the orifices being dilated.

Dr Max Mann³ found complete failure of the interventricular septum, with stenosis of the pulmonary artery, in the case of a woman who lived 22 years. In this case the aorta and the pulmonary artery were transposed.

Durozier records a case in which the patient lived for 39 years. I have not been able to obtain the original paper, but in the *Index Catalogue* the case is referred to in these words:—"Absence de la paroi interventriculaire; transposition de l'aorte et de l'artère pulmonaire; l'aorte s'ouvrant dans le ventricule gauche; rétrécissement de l'artère pulmonaire; deux sigmoïdes aortiques; absence de cyanose et de transposition des organes; homme de 39 ans.—*J. d. Conn. méd. prat.*, Par. 1885."⁴

When I described the specimen as being unique, I had not seen the record of Durozier's case; but that the specimen is a rare one is beyond doubt.

Dr Todd⁵ says that "the heart with three cavities (tricoilia of Hunter), that is, containing two auricles and one ventricle, or that form of heart which belongs to the Batrachian reptiles, must be very rare, if indeed it ever occurs."

Professor J. M'Farland⁶ referring to cases in which the interventricular septum fails to develop and the heart remains similar to that of the Amphibians, with two auricles and one ventricle, concludes that "such defects may not be incompatible with embryonal development, but life after birth is impossible, because of the inability of the individual to maintain its own circulation."

¹ *Krankheiten des Herzens*, vol. iii. p. 200.

² *Archives générales de médecine*, 1828, vol. xxiii. p. 83.

³ *Ziegler's Beiträge*, 1889, B. vi., p. 485.

⁴ *Index Catalogue of the Library of the Surgeon-General's Office, U.S. Army*, 2nd series, vol. vi. p. 857.

⁵ *Cyclopedia of Anatomy and Physiology*, 1836-39, vol. ii. p. 621.

⁶ *A Text-book of Pathology*, 1904, p. 394.

It is not easy to give an adequate explanation either of the causes of the malformation or its results. The solution of these problems appears to be beset with difficulties, but I would be inclined to lay stress on the transposition of the aorta and the pulmonary artery.

In Max Mann's case, that these vessels were transposed is positively affirmed. In Dixon Mann's case this was not absolutely proved; still, as already stated, the origins of the two coronary arteries of the heart from one trunk seem more than significant as to the distinction between the aorta and the pulmonary artery. It is true that occasionally a coronary artery arises from the pulmonary artery. St John Brooks records two such cases;¹ but I do not know of an instance in which both coronary arteries took origin from the same pulmonary trunk.

It was perhaps a little unfortunate that one had not the opportunity of making perfectly sure of the identity of the two great emerging vessels of the heart, but I think that the significance of the origins of the coronary arteries in this case is conclusive. The real difficulty, however, is, to explain how it happens that the aorta and the pulmonary artery are transposed.

Max Mann,² who gives a very full account of his case, suggests that the conus arteriosus was turned round to the extent of 180°. His exact words are as follows:—"Der grosse Septum defect (d. h. das gänzliche Fehlen eines mittleren Septum) sowie die Umstellung der grossen Gefässe ist die Folge einer in früher Zeit erfolgten Rechtsdrehung des Conus arteriosus um 180°."

It is difficult to accept Max Mann's explanation of the transposition of the aorta and the pulmonary artery. Seeing that the bulbus cordis, from which both vessels are derived, is originally a tube continuous with the primitive heart tube, it seems unlikely that one part of the tube should be rotated to such an extent as is suggested, whilst the rest of the tube remains apparently stationary.

In the early development of the heart, the asymmetrical growth of the ventricular part of the heart produces a well-marked auriculo-ventricular bend. The bend under normal circumstances is invariably to the right side, and it results in a sharp auriculo-ventricular angle. A second bend, directed towards the left, between the bulbus cordis and the ventricle, the bulbo-ventricular bend, in a similar way forms a sharp bulbo-ventricular angle.

Dr Keith suggests that the essential error of development which leads to the transposition of the aorta and the pulmonary artery is that the auriculo-ventricular bend, instead of bending to the right, is bent towards the left side. This explanation seems adequate, and I think it affords the best explanation of the transposition.

We have no right to assume that the initial change in these exception-

¹ *Journal of Anatomy and Physiology*, 1885, vol. xx. p. 20.

² *Loc. cit.*, p. 508.

ally rare anomalies of heart is a transposition of the aorta and the pulmonary artery; but if it is assumed, the further anomalies which ensue admit of a simple explanation.

In the specimen shown it is clear that the transposed aorta arises from the right side of the common ventricle, through the bulbus cordis; and it is obvious that during foetal life the arterialised blood from the placenta passed successively through the right and left auricles, and was directed to the left part of the common ventricle. It would then pass to the right part towards the aorta, in its course intermixing with the caval venous blood from the right auricle. The course of the main blood-stream would tend to interfere with the complete development of the interventricular septum, and so there would be no formation of right and left ventricular chambers.

Another problem one would like to solve is why, with such intermixture of the caval and pulmonary blood-currents, there is no cyanosis. It is abundantly evident from the anatomical characters of the heart shown that there is nothing in its structural arrangements to prevent the free intermixture; but clearly that intermixture does not necessarily cause cyanosis.

There are many theories as to the causation of cyanosis. The specimen shown at least proves that the question of intermixture is not the only factor.

It is not necessary, from the anatomical standpoint, to pursue the matter further; but my colleague, Professor Lorrain Smith, has been good enough to write me certain observations dealing with the causation of cyanosis; and since they will fittingly complete the somewhat crude remarks I have ventured to make in describing the unusual anomalies of this heart, I propose to add what Professor Lorrain Smith has written:—

“A special interest attaches to this case when it is considered in relation to the conditions which give rise to cyanosis. In general, cyanosis is due to any cause which prevents due oxygenation of the blood. In the round of the circulation, in physiological conditions, the venous blood, as it returns to the lungs for aeration, still contains a considerable amount of oxygen. On the other hand, the blood of animals that have died from suffocation is found to be practically deprived of all its oxygen. The condition of cyanosis arises when the blood as a whole contains a larger amount of deoxygenated blood than the normal circulating blood, and the degree of cyanosis varies within wide limits. It is impossible as yet to define these limits exactly.

“There has been a considerable amount of discussion on the question whether, in cases of congenital heart disease, cyanosis should be ascribed to mixture of the arterial and venous currents, or to venous engorgement in an embarrassed circulation. The case under consideration has an im-

portant bearing on the generally accepted doctrine that the mixture of venous and arterial blood in a single ventricle is, of itself, insufficient to cause cyanosis. We may consider how this conclusion can be applied to the case.

"From observations on animals it has been found that the blood in the arteries contains about 20 volumes per cent. of oxygen, and of this 10-12 volumes remain when it is returned to the heart by the veins. It has lost, therefore, about 9 volumes per cent. It would be easy to estimate the amount of oxygen contained in mixed blood, if we knew the relative amounts of arterial and venous blood in the mixture. We are unable to ascertain, however, the ratio of the quantity of blood passing through the lungs and entering the ventricle from the left auricle, to the quantity of venous blood entering the ventricle from the right auricle. That the quantity passing through the lungs was relatively large in this case seems probable from the large size of the pulmonary artery, and from the fact that where there is a single ventricle, as in this case, the pulmonary circulation is maintained by the same power as the systemic circulation. Here also, it should be noted, the wall of the ventricle was markedly hypertrophied. The larger the relative amount of the blood passing through the lungs, the less would be the deoxygenating effect of the mixing of the currents. That the relative volume of the blood passing through the lungs is an important element in these cases is clear, since, as Coats pointed out, in nearly all the cases of cyanosis of this type there is obstruction in the pulmonary artery. In such cases cyanosis might in part be due to the mixture of a small amount of oxygenated blood with a comparatively large amount of venous blood.

"In this case it is noted that cyanosis was present towards the end of life, when heart-failure was apparent. Delay in the circulation from cardiac failure would render the venous blood more and more deprived of oxygen, and in this condition the mixing of the currents would contribute to the cyanosis.

"From this case we learn something regarding the means by which the heart may still maintain an approximately normal circulation in spite of the absence of a ventricular septum. It seems doubtful if the sclerosis of the pulmonary valves seriously obstructed the current of blood passing to the lungs.

"The mass of blood which was driven through the lungs at each contraction of the ventricle would have much the same effect in causing hypertrophy as the mass which regurgitates in aortic incompetence. The presence of obstruction in the pulmonary orifice would diminish rather than increase the need for hypertrophy."

NEW STUDIES ON THE FOLDING OF THE VISUAL CORTEX AND
THE SIGNIFICANCE OF THE OCCIPITAL SULCI IN THE
HUMAN BRAIN. By G. ELLIOT SMITH, M.A., M.D., Ch.M., F.R.S.,
Professor of Anatomy, The School of Medicine, Cairo.

THIS is an abstract of one section of a communication dealing with the mode of folding of the visual cortex in the Primates, read before the Anatomical Society of Great Britain and Ireland in Belfast on 1st June 1906. The other subjects considered in that communication—(a) the arrangement of the area striata in the Apes, Lemurs, and other Mammalia; (b) the asymmetry of the occipital region of the cerebrum in Man and its effect upon the cranium; and (c) the variations in the occipital sulci—are being published elsewhere as separate papers.

This work is a sequel to that published in the *Records of the Egyptian Government School of Medicine* (1) two years ago.

If a coronal section be made through the occipital region (about 1 centimetre behind the fossa parieto-occipitalis) of a *perfectly fresh* human cerebral hemisphere—preferably the *left* hemisphere of a man (or woman) between the ages of thirty or forty years, examined within six hours after death—one can recognise (in most cases) with the unaided eye no less than eight strips of cortex each of which differs from the areas adjoining it in texture, coloration, the nature and mode of distribution of the intracortical matter, and, in some cases, also in thickness. If the brain be anæmic or that of a child or youth, it is impossible to recognise many of the distinctive features of the various regions. But in most cases the contrasts that are apparent to the naked eye in fresh sections of the brain of a non-anæmic adult are much more pronounced than those exhibited in sections stained by such a selective method as that of Weigert; and the process of mapping out the areas is simpler and gives much more exactly defined boundaries than can be obtained by the laborious reconstruction from serial sections stained by Nissl's method. Not only are the contrasts in the naked-eye method greater, but for other reasons the advantages of this procedure for a *purely topographical survey* are immeasurably greater than those of the alternative methods. In the process of mapping out any given area one can deal with a large piece of brain, and by making incisions with a scalpel at right angles to its borders can trace its edge

exactly, however irregular its outline may be, while still retaining intact the actual tissue of the region to be mapped; whereas by other methods not only must the area be cut up into sections, but in many of the slices the cortex will be cut so obliquely that it becomes impossible to determine the exact spot where the change in structure takes place. Much more important than this is the consideration that, by means of the macroscopic examination of fresh material, it is possible to obtain results (at least as accurate, if not more so) from at least two hundred specimens in the same time that it takes to examine one by the histological method. In this field of investigation this is a factor of the utmost importance, because there is such a wide range of variability that conclusions drawn from the study of one or even a dozen specimens, however complete the examination may have been, are liable to mislead. The process of folding of such a plastic material as the cerebral cortex does not always occur with mathematical precision along definite lines or in reference to fixed anatomical landmarks, so that it is often necessary to examine a very large number of specimens before we are able to determine the causal relationship between a furrow and the distribution of a cortical area.

The accompanying diagram (fig. 1) of a coronal section through the occipital region is intended to represent the causal relationship that exists between a large series of sulci and the distribution of various localised cortical areas: it is based upon the examination of nearly two hundred hemispheres. Although it is rare to find in one specimen every furrow exhibiting such a definite relationship to the edges or the axes of the various areas as this diagram exhibits, such cases do occur. This drawing in fact represents an actual section, and is diagrammatic only in the mode of representation of the texture of the cortical areas. It is quite common for the edge of an area, such as is represented in the diagram, stopping exactly in the floor of a sulcus, to cross the bottom of the furrow into the other wall for a few millimetres, or in other cases to stop before it reaches the floor. But when we consider how plastic a material the cerebral cortex is and how complex are the factors that exert an influence on it during its expansion, the wonder is, not that the coincidence of a sulcus and the boundary line between two areas should not be mathematically exact in every case, but that it should ever occur; and especially that this exact relationship should be found so often.

In these notes I shall not discuss the variations in the arrangement of sulci and the different modes in which the cortex may be packed in different brains. I shall devote a special memoir to the discussion of these matters: but in passing I may remark that the range of variation in the human occipital region is extraordinarily wide. At present I am simply

concerned with the consideration of the anatomical localisation of three cortical areas in the occipital region and the causal relationship of their distribution to a large series of sulci.

In this section (fig. 1) not only are both walls of the sulcus calcarinus (the posterior calcarine fissure of Cunningham—the sulcus retrocalcarinus (*miki*), defined as the “sulcus intrastriatus mesialis,” (5)) formed entirely of area striata (*i.e.* cortex containing the stria of Gennari—the line of

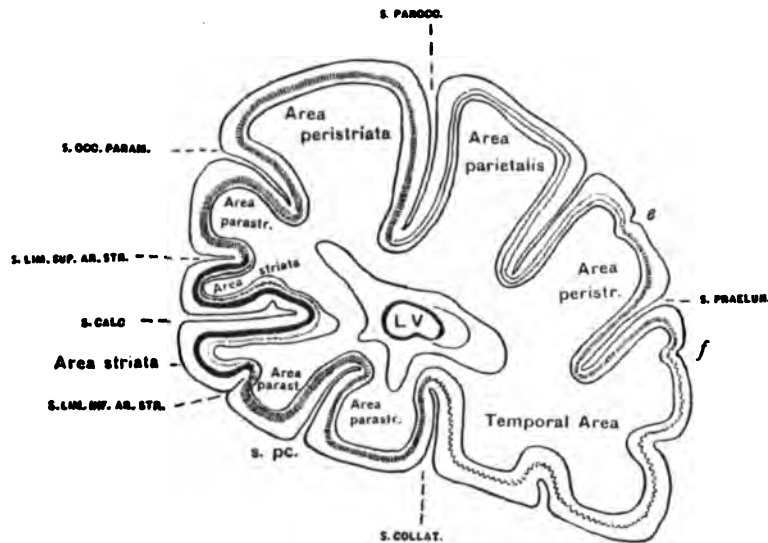


FIG. 1.—A diagram to represent the distribution of the different cortical areas in a coronal section through the left hemisphere of an Egyptian man one centimetre behind the fossa parieto-occipitalis.

L. V., posterior cornu of lateral ventricle; *s. calc.*, posterior calcarine sulcus; *s. lim. sup. ar. str.*, sulcus cunei (*s. limitans superior areæ striatæ*); *s. lim. inf. ar. str.*, sulcus lingualis (*s. limitans inferior areæ striatæ*); *s. pc.*, sulcus paracollateralis; *s. parocc.*, sulcus paroccipitalis (*s. limitans intraparietalis*); *s. praecur.*, sulcus occipitalis lateralis of Eberstaller (*s. praenatus*); *e* and *f*, sulci limitantes areæ peristriatæ.

Vicq d'Azyr), but part of the cuneus above it (see also fig. 2) and part of the lingual convolution below it are also formed of area striata. The dorsal boundary of the area striata in the cuneus is the furrow (figs. 1 and 2, *s. lim. sup. ar. str.*), which Retzius (2, p. 137) has called “sulcus sagittalis inferior cunei,” a term which might with advantage be shortened to sulcus cunei. It is one of the two furrows which Wilder (6, p. 189) has called “intracuneal.” In a previous memoir (5), I have defined this furrow as the “sulcus limitans superior areæ striatæ.”

The ventral boundary of the area striata in the lingual gyrus is the

furrow (figs. 1 and 2, *s. lim. inf. ar. str.*) which Retzius has distinguished by the name "sulcus sagittalis gyri lingualis." In shortening this name to "sulcus lingualis," I shall at the same time define it as the sulcus limitans inferior areæ striatæ. In the lingual gyrus there may be two sulci or only one: in the latter case the furrow may be a sulcus limitans areæ striatæ or a sulcus limitans inferior areæ parastriatæ (fig. 1, *s. pc.*, and fig. 2, *s. paracollateralis*). Retzius's term does not distinguish between

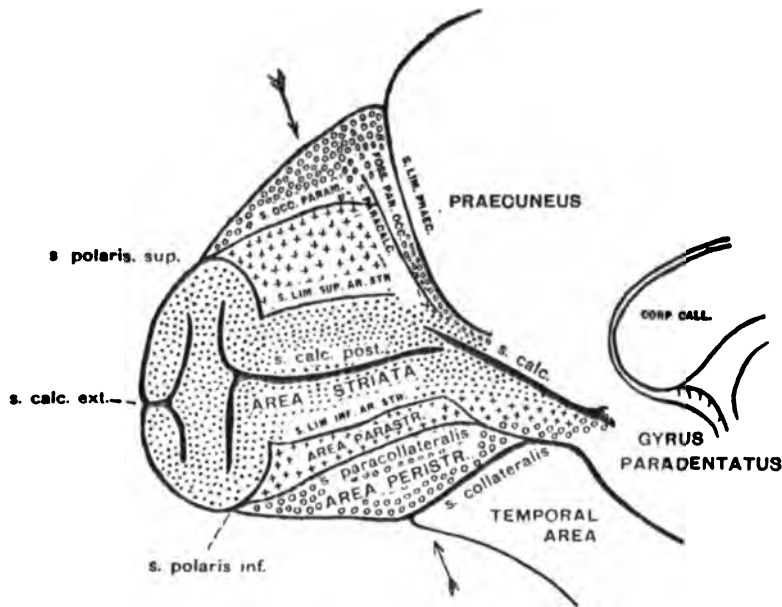


FIG. 2.—Diagram to illustrate the distribution of the cortical areas on the mesial surface of the occipital region of the left hemisphere.

The two arrows indicate the plane of the section shown in fig. 1. The area striata is represented by dots; the area parastriata by crosses; the area peristriata by circles.

these two furrows. In introducing the term "sulcus lingualis," I wish to give it more precision by applying it definitely to the former sulcus, and shall call the latter "sulcus paracollateralis."

If the sulci cunei et lingualis be traced backward, it will be found that in many cases (fig. 2) these furrows each join a semicircular sulcus, which Bolton has called "polar" (7, p. 171). Adopting this term, I shall distinguish these furrows as the sulci polaris superior et inferior respectively. The distinction between the cuneal and the polar furrows is one which is peculiarly characteristic of the occipital region. The polar sulci belong to the same type as the sulci lunatus, occipitalis inferior, and sometimes the

parieto-occipital fossa; the area striata extends as far as the lip of all these furrows without entering into the formation of their walls; in the case of the cuneal and lingual sulci the area striata extends into the furrow and stops in its floor (fig. 1). The former type of sulcus may be succinctly defined as "operculatus" and the latter as a "sulcus limitans." The sulcus calcarinus posterior belongs to yet a third group—axial furrows, formed by the infolding of one cortical area (fig. 1).

The area striata usually extends on to the lateral surface of the hemisphere and is folded axially to form the sulcus calcarinus externus of Cunningham (fig. 3, *s. calc.*), which I have defined in an earlier memoir

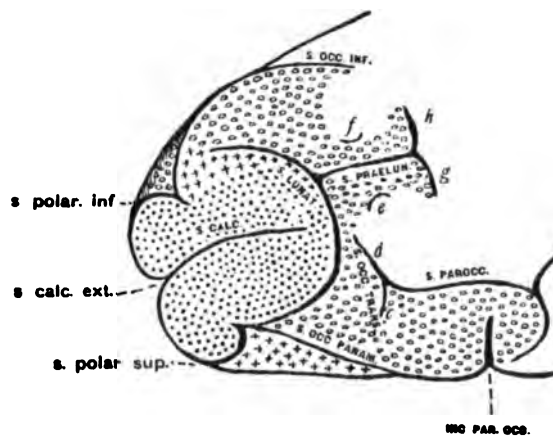


FIG. 3.—Diagram representing a dorso-lateral view of the occipital region of the same hemisphere.

(5) as the sulcus intrastriatus lateralis. In my earlier memoirs I have called this furrow by various other names—"sulcus occipitalis lateralis" and "sulcus occipitalis superior," which I now definitely discard in favour of Cunningham's term, "external calcarine," which so happily suggests the exact analogy between this sulcus on the lateral surface (fig. 3, *s. calc.*) and the posterior calcarine on the mesial surface (fig. 2, *s. calc. post.*). The accessory intrastriate sulci, which often surround the external calcarine sulcus, have been omitted from this diagram (fig. 3) because they are of no morphological importance. When it happens that the V-shaped accessory intrastriate sulcus, that is often present surrounding the external calcarine, parallel to, *i.e.* concentric with, the sulcus lunatus, is placed around the edge of the area striata, the coincidence is fortuitous and has no causal relationship; for in most cases where such a V-shaped sulcus is present the

area striata extends beyond it and ceases either exactly at or close to the caudal lip of the sulcus lunatus (fig. 3).

The true sulcus calcarinus (fig. 2, *s. calc.*)—the stem or anterior calcarine fissure of Cunningham—is a sulcus præstriatus, *i.e.* a sulcus limitans anterior areæ striatæ in *most* human brains. In other words, the area striata forms its caudal (ventral) wall only and stops in the floor of the sulcus. When the gyrus cunei is reached, the area striata crosses the floor of the furrow and extends exactly as far as the crest of the small gyrus: as the latter rises to the surface of the cuneus the edge of the area striata

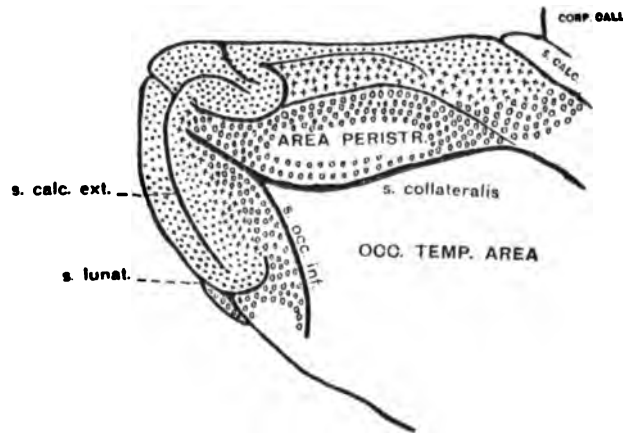


FIG. 4.—Tentorial aspect of the same.

continues to maintain this same relationship. It occasionally happens that the area striata extends to the caudal lip of the fossa parieto-occipitalis in the whole of this furrow's extent. In such cases the parieto-occipital fossa falls into the class of "sulci operculati," whereas in most instances it is a complex furrow of the class of "sulci limitantes."

THE AREA PARASTRIATA AND ITS LIMITING SULCI.

At the bottom of the sulci cunei et lingualis the cortex containing the stria Gennari comes to an abrupt end (fig. 1) and gives place to a cortical strip presenting very different features, which I shall distinguish as the "area parastriata." Neither Bolton nor Campbell has drawn any distinction between this area and that which I shall next describe under the name "area peristriata": the two regions are included by them in the "psycho-visual area" of Bolton.

Brodmann (9), however, clearly distinguishes these two areas on the mesial surface of the hemisphere of a *Cercopithecus*: but I cannot harmonise his map of the lateral distribution of these areas with my own results. The area parastriata is represented by Brodmann's "occipitaltypus" (typus 18), the histological features of which he has defined on page 190 of his memoir (9) and represented in Tafel 9. He refers to a description of this area in the human brain by Oskar Vogt (*Journal f. Psychologie und Neurologie*, Bd. ii., Taf. 10, fig. 2), which is not accessible to me.

In sections of the fresh human brain this cortical area is distinguished by the absence of any definite line of Baillarger, but the inner half of the cortex is characterised by a diffuse paleness which merges into the general medullary mass of the hemisphere with only a very faintly marked and quite indefinite layer of grey matter intervening between them.

It is limited above by the sulcus paramesialis (figs. 1 and 2, *s. occ. parum*). This is the sulcus sagittalis superior cunei of Retzius (2, p. 137), but I retain my own term because it is more appropriate. The sulcus in question is often not in the cuneus but on the dorsal surface of the hemisphere. It may be defined as the sulcus limitans superior areæ parastriatæ.

There is sometimes a sulcus limitans inferior areæ parastriatæ in the gyrus lingualis, which I shall call "sulcus paracollateralis" (fig. 1, *s. pc.*, and fig. 2).

Posteriorly the area parastriata is often buried in the polar sulci and laterally in the sulcus lunatus—although a small part of it may be exposed near the edge of this furrow (fig. 3).

Anteriorly the edge of the area parastriata is buried in the fossa parieto-occipitalis, and the most caudal of the three furrows in this fossa—the sulcus paracalcarinus of my earlier memoirs—becomes the sulcus limitans anterior areæ parastriatæ (fig. 2).

THE AREA PERISTRIATA AND THE FURROWS RELATED TO IT.

Beyond the ring of parastriate area the diffuse paleness of the inner half of the cortex gives place to a definite band of Baillarger not quite so narrow or dense as the stria of Gennari but almost as distinct. Unlike the condition seen in the parastriate cortex, there is a definite band of grey matter separating the intracortical white band from the general medulla in this region, which I shall call "area peristriata." It seems to be identical with the region which Brodmann calls "præoccipitaltypus" (typus 19) in the brain of *Cercopithecus* (9, p. 191).

It is impossible to recognise from Campbell's account of the locality

from which his sample of "visuo-psychic" cortex was obtained whether it was para- or peri-striate, because "a section of the superior occipital gyrus, midway between the top of the parieto-occipital fissure and the posterior extremity of the hemisphere" (8, p. 312), or "2 cm. anterior to the tip of the lobe" (p. 310), are quite inadequate as topographical directions, when it is recalled that the area striata may stop at the "tip of the lobe" or extend as much as 4 cm. beyond it. The histological features of his visuo-psychic area (plate xi., fig. 2) seem to resemble most those of my parastriate area.

On the mesial surface of the hemisphere the area peristriata occupies the floor of the fossa parieto-occipitalis, and extends as far as the anterior sulcus buried in that depression, which I have called sulcus limitans "præcunei." So that this furrow might also be defined as the sulcus limitans anterior areæ peristriatæ (fig. 2).

When the paramesial sulcus is found on the mesial surface (fig. 2, *s. occ. param.*), a strip of peristriate cortex occupies the upper part of that surface, as well as the dorsal edge of the hemisphere. Thence it extends as far outward as that portion of the intraparietal sulcus of Turner which Wilder has called "paroccipital." As this is a natural subdivision of the large composite sulcus—intraparietal—and is genetically distinct from the remainder, it is convenient to use Wilder's term. The paroccipital may be defined as the "sulcus limitans dorsalis areæ peristriatæ"; whereas the rest of the intraparietal is the limiting sulcus separating the two parietal lobules.

It is interesting to observe that whereas the main stem (fig. 3, *s. parocc.*) and its mesial cephalic (fig. 3, *a*) and lateral caudal (*d*) branches are essential parts of the limiting furrow, the lateral cephalic (*b*) and the mesial caudal (*c*) branches are morphologically unimportant furrows, being apparently mere kinks resulting from the mechanical conditions incidental to the bending of the cortex at these points. Like the mesial part (*c*) of the transverse occipital furrow (*s. occ. trans.*), the incisura parieto-occipitalis is also merely an indentation in the area peristriata, probably due to the mere mechanical inbending of the floor of the fossa parieto-occipitalis between its two limiting sulci.

A considerable part of the area peristriata is often hidden under cover of the operculated caudal lip of the sulcus lunatus, but a process always stretches out toward the auditory centre (but without reaching it), and this usually becomes folded longitudinally to form an axial sulcus, which in former memoirs I have called the sulcus prælunatus (fig. 3, *s. prælun.*). This furrow usually ends anteriorly in a T-shaped piece (fig. 3, *g* and *h*), the vertical part of which forms an anterior limiting sulcus of the area peristriata. Small additional limiting furrows (fig. 3, *e* and *f*) are often

found at the margins of the peristriate area. I have elsewhere (1, plate A, figs. 2 and 3) published photographs of a brain almost exactly similar to that represented in the diagram (fig. 3). The ventral limit of the peristriate cortex on the lateral side is the sulcus occipitalis inferior (fig. 3, *s. occ. inf.*), just as the sulcus collateralis forms its inferior boundary mesially (figs. 2 and 4).

As there may in some cases be doubt as to the identity of the collateral sulcus (see on this subject Zuckerkandl, 3), I may state that the sulcus limitans inferior areæ peristriatæ mesialis is precisely that part of the furrow which indents the ventricular wall to form the eminentia collateralis.

At the bottom of the paroccipital sulcus the area peristriata becomes continuous with the great parietal association area of Flechsig (fig. 1), and on the tentorial surface in the floor of the collateral sulcus it becomes continuous with the temporal (or temporo-occipital) association area. Stretching forward so as to separate the caudal ends of these two areas, we find the process of peristriate cortex which becomes folded to form the prelunate sulcus. There can be little doubt that this patch of cortex is identical with the "area 12" of Flechsig, which he calls the "gyrus subangularis" (10).

Nor can there be any question that the sulcus prælunatus is anything else than Eberstaller's "sulcus occipitalis lateralis." The latter term has been applied to various other totally distinct furrows. Zuckerkandl has justly criticised my error of confusing this furrow and the sulcus lunatus (4, p. 237), yet in the same memoir (4, fig. 7, p. 228) he himself has labelled the lower part of the sulcus lunatus "*S. occipitalis lateralis*"; and in other memoirs he has applied the latter term to the sulcus occipitalis inferior in the apes (11, fig. 11, p. 47). To these two undoubted mistakes there is yet a third error in identification to be mentioned. I was misled by a statement made by Retzius (2, p. 136) into the belief that Cunningham regarded his external calcarine and Eberstaller's lateral occipital sulci as identical, and used the latter term for the external calcarine in my part of the Catalogue of the Brains in the Museum of the Royal College of Surgeons. I now recognise (as I have stated in previous publications) that I was quite unjustified in this belief.

As there can be no question that the sulcus that I have called "prælunatus" is identical with Eberstaller's "occipitalis lateralis," the former term may be discarded.

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REPORT ON A CRANIUM WITH GREATLY REDUCED AND
IRREGULAR DENTITION. By W. L. H. DUCKWORTH, M.D., Sc.D.

AMONG recent additions to the osteological section of the Anatomical Museum is part of an adult male cranium from a student's set of bones, which was obtained by Dr E. Barclay Smith. The chief feature of interest (*cf.* fig. 1) is the reduced number of the upper teeth (only the upper maxilla

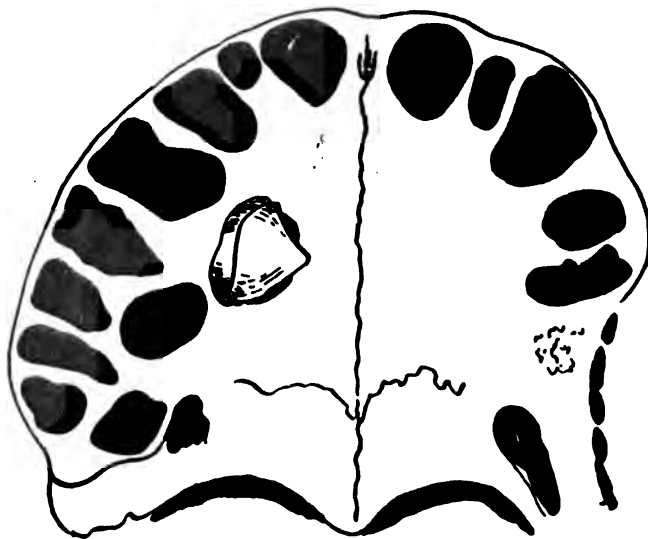


FIG. 1.—Tracing from a photograph of the palatine aspect, to show the second right premolar tooth appearing on the hard palate, and the very small sockets for the two lateral incisor teeth.

could be examined), the smallness of the palate, and the very orthognathous profile of the skull, which is no doubt directly associated with the two preceding characters. The characters of the teeth can only be inferred from the appearance of their sockets, except in one instance. The median incisors were of normal size, or even rather larger than usual; but the lateral incisors were both small, and in particular that on the right side must have been minute, for its socket measures only 2 mm. in diameter (the right median incisor socket measuring 6 mm.). The left lateral incisor socket measures 3 mm. x 5 mm.

The canine teeth were present, and that on the left side was normal in size, but the right was abnormally small (socket $3.5 \times (?) 5$ mm.). Behind the canines, further irregularities occur.

Thus, on the right is a socket for a premolar of about the normal dimensions; but, between this and the normally developed tripartite socket

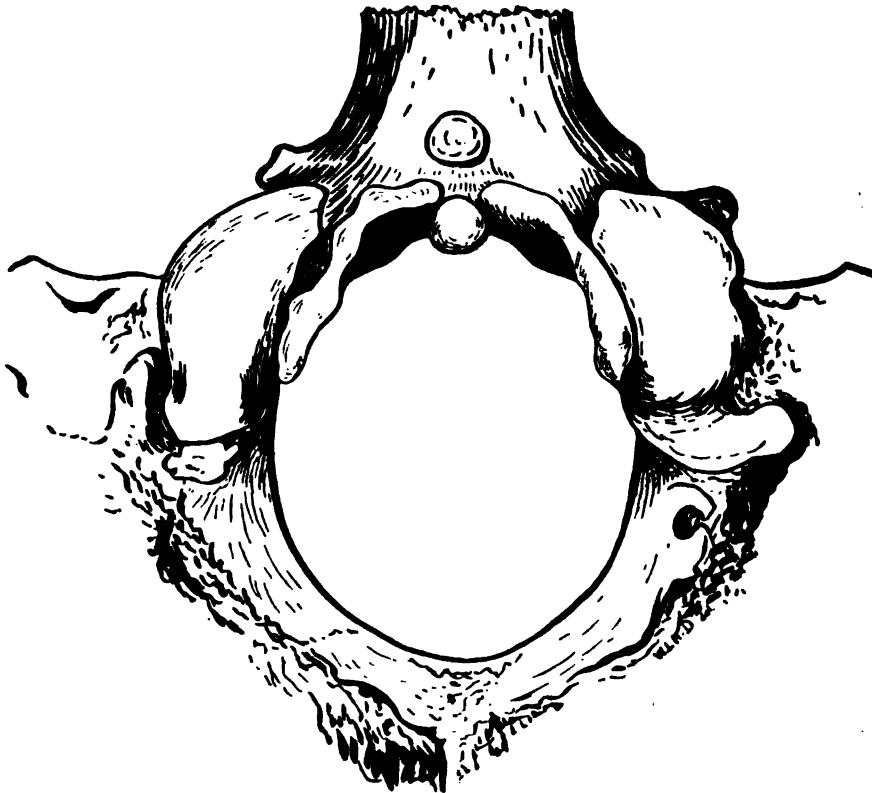


FIG. 2.—Tracing from a photograph of the base of the skull, to show the anomalous tubercles on the anterior margin of the foramen magnum.

of the first molar, the second premolar has been erupted on the surface of the hard palate, with its crown directed towards the mid-palatine line. This is the only tooth left in the skull, and it is well formed, and of course not worn down. No special remarks attach to the first and second molar teeth, and no third molar was developed, although the subject was adult. On the left side, the first premolar tooth must have been lost during life, and its socket obliterated by absorption. Behind the space thus left is a large simple socket, probably occupied in life by a premolar tooth with the

two roots fused—and therefore degenerate. Behind this socket, the alveolar margin has been entirely destroyed by inflammatory processes (alveolar abscess), so that it is not possible to state what teeth, if any, had ever been present here. Such are the main features of the dentition.

For similar examples of teeth diverted to the palatine surface, reference may be made to *Studies from the Anthropological Laboratory* (Series I., p. 279), where I have recorded comparable instances in European and Hindu skulls.

The palate is very small; both length and breadth are reduced, but more particularly the former dimension. The value of this (42 mm.) may be compared with the figures derived from five East Anglian skulls, the smallest of which provides a palate 50 mm. in length (*Studies, etc.*, p. 265). The palatine breadth is not so notably reduced.

The relatively small dimensions of the palate (length 42 mm., and breadth 48 mm.) may be seen on comparing them with the length and breadth measurements of the cranium (viz. 180 mm. by 140 mm.), which is not far removed from the average in point of size. Two or three other points remain for notice.

As is shown in fig. 2, there is a distinct median tubercle (3 mm. wide) on the anterior margin of the foramen magnum. This is quite distinct from a median unpaired pharyngeal tubercle found on the basi-occipital bone, but situated in advance of this marginal tubercle. The latter lies between two lateral tubercles, each of these being clearly a derivative of the corresponding occipital condyle. It is not common to find both median and lateral tubercles in the same skull.¹

The sphenoidal spines are broad or spatulate, and large. The partition between the inferior petrosal sinus and the sigmoid sinus is completely ossified on each side, and thus divides the jugular fossa into two compartments.

¹ Cf., *inter alia*, Kollmann, "Anatomischer Anzeiger," *Ergänzungsheft zum xxvii. Band* (1905) *Verhand. der Anat. Ges. auf der Versamm. in Genf*, pp. 231–236. References to many records are provided.

DESCRIPTION OF A HUMAN CRANIUM FROM WALFISCH BAY,
S.W. AFRICA. By W. L. H. DUCKWORTH, M.D., Sc.D.

PROFESSOR MACALISTER, having recently purchased for the Cambridge Museum a collection of crania from Madagascar and South Africa, placed in my hands for examination the specimen which forms the subject of this note. The chief point of interest is the bilateral appearance known as "os malare bipartitum." The condition has been recorded in crania from various parts of the world. The most recent examples I have seen were crania of a Korean and a Magyar respectively, shown to me in Berlin by Professor von Luschan. The anomaly is fully dealt with by Professor Ledouble in *Les variations des os de la face*.

The cranium, which is small, bears the following marks: "Walfisch Bay, J. J. Cheverly, R.M. vii. 05 (30)." The skull seems to be that of a small adult native woman. In point of size it is similar to crania of Bush natives of South Africa, and even smaller than some Bush crania in the Cambridge Collection. It is nearly perfect, and has been bleached by exposure: only the left zygomatic arch is imperfect, and hardly any teeth remain, having probably fallen out, since the sockets in most cases persist.

In *norma verticalis* the form is rhomboidal, closely resembling the contour of a Tasmanian skull in the Cambridge Collection. The temporal ridges do not, however, rise very high on the skull, never approaching each other nearer than 106 mm. Very deep grooves mark the course formerly taken by the branches of the supra-orbital nerve on the upper part of the left frontal bone; these grooves are much less distinct on the right side. They are very common in crania of African negroes (especially the Bantu race), and occur in Bush crania. The cranial sutures are finely serrated, and synostosis has set in near the obelion and about 20 mm. behind the bregma, in the sagittal suture.

In *norma lateralis* there is distinct but moderate prognathism, in spite of the value obtained for the alveolar index. The nasal bones and nasal processes of the superior maxilla are not prominent, but yet are not so flattened as in many African negro crania. The alveolar margin of the maxilla projects, but is not massive. The brow ridges are but feebly developed (this is, of course, a feminine character): the forehead has the distinct African negroid prominence above the ophryon. The occiput

bulges slightly: there is no definite external occipital protuberance. In fact, the occipital end of the cranium is distinctly feminine in its conformation.

The mastoid processes are small, as are also the conoid processes. The squamosals do not rise high on the lateral wall of the cranium, but their upper margins are distinctly notched where crossed by the temporal crest.

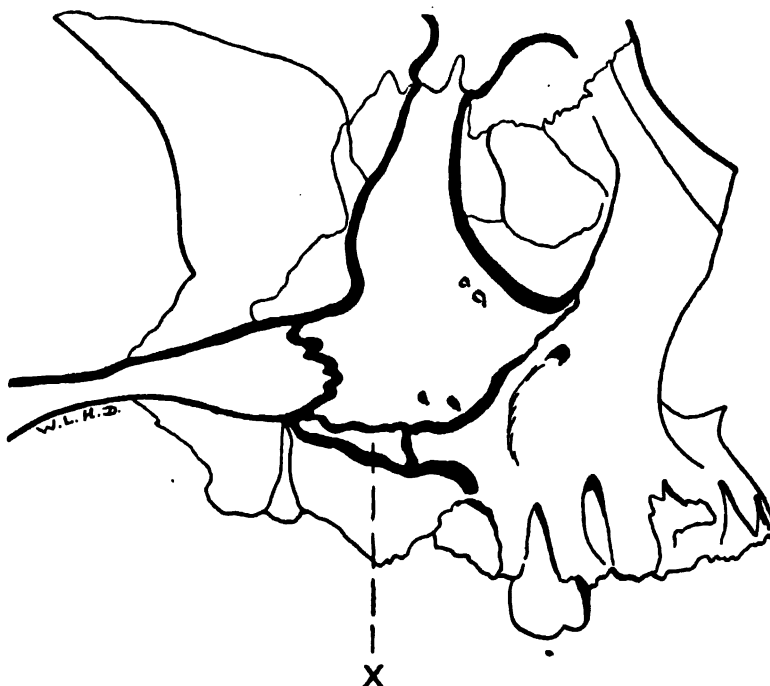


FIG. 1.—Right side of the skull from Walfisch Bay. *x* is the lower part of the bipartite malar bone.

The malar bones are very striking, for they present the double form which constitutes the commonest anomaly of these bones. The lower component has, however, joined the superior maxilla, which therefore appears (*cf.* figs. 1 and 2, *x* and *x'*) to run along the zygoma below the malar bone and to support it, forming an infra-jugal arch. On the right side this fusion (of part of the malar with the superior maxilla) is incomplete, and leaves a small fragment of malar touching the remainder of the malar above, and articulating with the maxilla in front and the temporal behind (*cf.* fig. 1, *x*).

The ali-sphenoid sends a tongue-like process some distance along the upper border of the squamosal; but on each side of the pterion the parietal and sphenoid bones join, and separate the frontal and temporal bones.

In *norma facialis* the face appears infantile or feminine. No specially



FIG. 2.—Left side of the skull from Walfisch Bay. *x* is the lower part of the bipartite malar bone, here united with the superior maxilla.

unusual features are observed in or about the orbital cavity. The nasal bones are flattened and the nasal aperture is pyriform, with margins that become less sharp towards the small, sharp nasal spine, but which never become entirely obliterated. In this *norma*, the cranial vault behind the bregma is seen to be distinctly scaphoid or carinate.

In *norma basilaris* the palate is seen to be small, but broad; the palatine sutures are regular, and the post-palatine spine distinct. Portions of three teeth in the upper jaw remain, viz. the first right upper molar

tooth, and the two left upper premolars. They are much worn, but white and clean. Signs of alveolar abscesses are, however, very distinct.

The glenoid fossæ are moderately deep. The petrous bone encroaches on the anterior lacerate foramen, so that the latter is very small, and the carotid canal is thus fully closed below. The styloid processes are very short, and the tympanic bones are not large, so the external auditory meatus is consequently very shallow. The occipital condyles are very small and not greatly elongated in the sagittal direction. The paracondylar processes are practically non-existent.

The mandible is very peculiar. The angle is very large, and this feature, combined with a shallow sigmoid notch, gives this small mandible a very infantile appearance. The chin is, however, distinct, though not so prominent as in European mandibles. No teeth remain, but there are very clear signs that the molars on each side were affected by alveolar abscesses.

The right side of the mandible presents a remarkable appearance, for the bone is defective at the angle, part seeming to have been removed. The remaining bone is quite smooth, so that, if the condition is the sequel to an accident, no extensive inflammation and no widespread necrosis occurred at the time. It might be thought that the condition is due to a defect in development, the "angular" centre of ossification being absent on this side. But examination of the specimen leads me to conclude that traumatic causes (and not defective ossification) are responsible.

Apart from the anomalous condition of the malar bones and zygomatic arches, the small size of the skull suggests a comparison with the female Bush cranium. In point of size there is little or no difference; but the conformation of the face in the Walfisch Bay specimen shows clearly that it is not like the ordinary Bush skull; for the face is too prognathous, and, in particular, the nasal bones and maxillæ are not so flattened, nor is the forehead so high, as in normal Bush skulls, whether male or female. It is curious, however, to remark that in these very points (as well as in its small dimensions) the Walfisch Bay skull is closely approached by the skull of a skeleton in the Cambridge Collection labelled "Bushwoman." The latter skeleton and a male skeleton of similar pygmy stature (marked "Bushman") were purchased very many years ago for the Anatomical School, and appear in the old Catalogue as having been bought in Paris from a certain M. Dumoutier. In neither of these two skeletons is the cranium typically Bush in its conformation, and doubts have long been cast on the accuracy of the designation. For the present, I incline to believe that they and the Walfisch Bay specimen are representatives of races inhabiting South-West Africa (such as the Hill-Damaras), and only remotely allied to the true Bush race.

The principal dimensions of the Walfisch Bay skull are appended.

MEASUREMENTS OF SKULL (in millimetres).

A small (probably female) skull from Walfisch Bay, S.W. Africa.

Cranial portion:

Maximum length	169
Glabello-occipital length	168
Maximum breadth	131
Basi-bregmatic height	122
Horizontal circumference	483
Auricular height	111

Facial portion:

Basi-nasal length	93
Basi-alveolar length	93
Nasi-alveolar length	52
Bi-zygomatic breadth	116
Orbital height	31
Orbital width	36·5
Nasal height	41
Nasal width	24·5

Indices:

Cephalic	77·51
Altitudinal	72·19
Alveolar	100·00
Facial (Kollmann's)	44·83
Orbital	84·93
Nasal	59·75
Intercondylar line to mental symphysis	99
Corono-condylar length	43·5
Height of coronoid process (left)	42

SOME RARE ABNORMALITIES IN TEETH. By W. RAMSAY
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WHEN making inquiries into the dentition of Australian aboriginals and South Sea Islanders, I took occasion to show some interesting teeth to Professor Watson, of the Adelaide University, and Mr Crank, D.M.D. In the course of our examination, Dr Crank produced several teeth which I had asked him to present to odontological collections; and Professor Watson thought it was a pity they should go undescribed, seeing that they presented some very rare abnormalities, and he made me promise to prepare a description for publication. The following is the result.

No. 923.¹—Fusion of two upper central incisors, from a boy 8 years old. These grew on the right side of the mouth, in the place where the lateral incisor and canine should be. They made the lower lip so sore that he had to hold it out when eating.

The mass measures 23 mm. in length and 13 mm. in greatest width. The roots are nearly equal in size; but the right crown is larger than the left. The large, single, constricted pulp-cavity is surrounded by a thin tube of dentine. The vertical ridge on the front (fig. 1) belongs to the right tooth; the line of demarcation between the teeth passes downwards on its left, and makes a notch on the border at a distance of 5 mm. from one border and 8 mm. from the other. On the cutting edge of the left tooth there are five small pits, and on the edge of the right there are ten. The posterior surface of the mass (fig. 2) shows great growth of the cingules of both, which gives rise to very deep vertical pits.

The point of greatest interest here is the small amount of separation to be observed in the case of central incisors, which grow in separate bones. Fusion to an equal extent to this is figured by Tomes (fig. 3) in the case of central and lateral incisors in the upper jaw (*Dental Surgery*, 3rd ed., p. 129). Tomes has also figured a case (fig. 4) of fusion of two upper central incisors by their crowns, and a relatively small portion of their roots, the greater bulk of the roots being distinct (*Dental Surgery*, 3rd ed., p. 128). There appears, however, to be no recorded instance of such fusion as I now describe.

No. 850.—Two lower canines with double roots. The first (figs. 5, 6)

¹ The numbers refer to the catalogue of my series of pathological specimens.

measures 25 mm. in length, and 9 mm. in greatest width. It shows complete bifurcation of the root for a distance of 7 mm. The double nature of the root is shown by well-marked grooving, continued on each side up to the level of the neck. The roots are nearly equal in size. On the crown the labial stanchions, four or five in number, are well marked. Otherwise the crown is normal. The second (figs. 7, 8) also measures 25 mm. in length and 9 mm. in greatest width. The root is



FIG. 1.



FIG. 2.



FIG. 3.



FIG. 4.



FIG. 5.



FIG. 6.

bifurcated for a distance of 7 mm. The interesting point in connection with this specimen is that the two roots are unequal. The buccal root is the main one, and it shows grooving which divides it roughly into two. The labial root looks like an adventitious root that has become fused in its upper part to the inner surface of the otherwise normal and grooved root of the canine, the grooving being distinct up to the enamel. On the crown are three well-marked stanchions.

No. 924.—A good example of "concrecence" of teeth is afforded by the first upper left molar, with the second molar nearly reversed (fig. 9), the two being firmly fixed together by their roots. Both teeth are of

large size, and each has three roots. The angle enclosed by the long axes of the teeth is about 140° . Hypercementosis is well marked in connection with both teeth. The phenomenon of concrescence seems to be less common between the first and second molars than between the second and third molars. The case figured by Burchard (*Dental Pathology and Therapeutics*, 2nd ed., p. 224), of second and third molars, shows roughly an angle of 90° . Tomes (*Dental Surgery*, 3rd ed., p. 130) shows drawings of a case where the angle was about 50° , and another (p. 237)



FIG. 7.



FIG. 8.



FIG. 9.



FIG. 10.



FIG. 11.



FIG. 12.



FIG. 13.



FIG. 14.

where the wisdom (fig. 10) was completely inverted and embraced within the roots of the second molar. Dr Cryer, in *The American Text-book of Operative Dentistry*, p. 593, figures six cases of this condition, without stating what the teeth are.

No. 925 is an upper left wisdom of a male 38 years old. It possesses four roots, but it has other characters that are of much greater interest. On the lingual margin of the crown there are two small enamel tubercles (fig. 11), and from the enamel of the crown an enamel ridge runs upwards to end at the bifurcation of the roots in a line with one of the tubercles.

This condition is of interest in connection with another tooth, No. 926. The Curator of the Museum at Noumea, New Caledonia, was good enough to allow me to examine certain native necklaces made of Kanaka teeth, and to take what I wanted. I inspected several hundred teeth, and took one specimen. It exhibits a little pearl-like enamel tumour at the junction of a labial with a lingual root (fig. 12). A specimen of this sort is figured by Burchard (*Dental Pathology and Therapeutics*, 2nd ed., p. 226). He says:



FIG. 15.



FIG. 16.



FIG. 17.



FIG. 18.



FIG. 19.



FIG. 20.



FIG. 21.

"A small nodule or cap of enamel overlying dentine, and itself overlapped at the edges by cementum, may be found upon the root of a molar, usually upon the side of an upper third molar at a point about $\frac{1}{4}$ inch from the cervical margin of the crown enamel. A thin ridge of enamel sometimes, though not usually, seen connecting them indicates the nodule to have been formed by a detached portion of the original enamel organ. This formation is known as an enamel nodule. It may occur upon a lower molar, though usually found upon the upper molars" (fig. 13).

Mr S. J. A. Salter, in *A System of Surgery*, Holmes and Hulke, vol. ii. p. 461, figures an instance (fig. 14) which he describes as a characteristic

specimen. He refers to his description of these growths in *Guy's Hospital Reports*, 1869. He says that these enamel nodules, forming little pearl-like tumours, are essentially *submerged cusps*, each consisting of a little cone of dentine, covered by a thick tubercle of enamel, which is clothed by a true enamel-pulp.

It will be seen that in all three instances the tumour occurs between the labial and the lingual roots, and also that in all three a ridge of enamel runs from the tumour to the crown. The Kanaka tooth, however, shows an additional feature of interest, viz. a small cusp at the margin of the crown, and a smaller one near it which is situated at the extremity of the enamel ridge running from the enamel tumour. The tumour is also at a much greater distance from the crown than in either of the two other specimens. This tooth is of great interest in connection with Salter's theory of submerged cusps.

The subject from which the Kanaka tooth had been taken appears to have been a young one, since the three roots are incomplete and show the "persistent pulp" structure.

No. 927 (fig. 15) is an upper left wisdom from a male 19 years old. The condition of two of the roots is one of apposition, not fusion. The root most bent is grooved and slightly forked at its extremity, and the tips of all the fangs consist of very dense dentine and cementum.

Nos. 928, 929, and 930 are two upper canines and a left first bicuspid from a male 55 years old (figs. 16, 17, 18). They show long, thick, peg-like roots.

No. 931 is a lower right first molar from a boy 12 years old. The amount of grooving exhibited (fig. 19) suggests five roots.

No. 932 is a lower left wisdom from a girl 16 years old. It is remarkable for the association of a large number of cusps with a single long, peg-like, bent root (fig. 20).

No. 933 is a lower right second bicuspid from a subject 14 years old. The amount of grooving exhibited suggests four roots (fig. 21).

With the exception of the Kanaka's tooth, all these specimens are from white people, and most of them were given me by Mr Mallan and Mr Maughan, dentists, of Adelaide, to whom I feel much indebted for the opportunity of describing such interesting abnormalities.

NOTES ON A PREHISTORIC SKELETON FOUND IN A CAVE IN
LITTONDALE, YORKSHIRE. By C. A. HILL, Esq., B.A., M.B.,
B.C. (Camb.), *Liverpool*.

IN October 1905, the members of the Yorkshire Ramblers' Club, whilst exploring a cave in the limestone scars of Littondale, one of the upper branches of Wharfedale, found, scattered along the floor of the cavern, three bones, which, on inspection, were pronounced to be human. Many caves in Yorkshire and elsewhere have yielded animal remains, such as the bones of the hyena, the rhinoceros, the bear, and the wolf; but human remains have never been found before in such a situation. One of the party, who is a medical student, happened to be staying in the neighbourhood, and had his curiosity so whetted by this unique discovery that he resolved to re-enter the cave and search for more of the skeleton. He was rewarded by finding a considerable number of bones, including the skull, many of them being almost completely embedded in stalagmite, necessitating very careful extraction. On hearing of this find during the winter, I determined to prosecute a further search, and, with this intention, have visited the cave on three occasions during the present year. I have been successful in adding considerably to the number of bones, but the skeleton is as yet incomplete. (A complete list, with measurements, is appended.) All these bones are of a dark brown shade, more particularly the portions which were exposed, and were so coloured by the action of the peaty water which flows through the cave in small quantity. This, combined with the action of the carbonate of lime in which most of them were buried, has undoubtedly acted as a preservative.

The annexed plan (fig. 1) shows the extent of the cave, so far as it has been explored and surveyed up to the present. I will now give a brief account of its physical characteristics. The distance from the entrance to the part where the bones were found is 240 yards. The entrance itself is lofty, being 7 feet high and 15 feet broad, so that one can walk in comfort. In times of flood, a small stream issues from the cavern's mouth, and, by a series of cascades, finds its way to the river Skirfare below. Having traversed the first and loftiest portion of the cave, the passage, about 75 yards from the entrance, expands into a small chamber, on the left-hand side of which an opening is seen underneath a low ledge of rock,

the main passage continuing to the right. The left branch is entered by crawling under the ledge, barely 18 inches high, through a pool of water covering a bank of mud. In a few yards the roof rises, and one can again walk upright. Proceeding onward, the roof gradually becomes lower and lower, until progress is only possible by crawling through the thin stream that trickles along the floor. At the point where the bones were found,

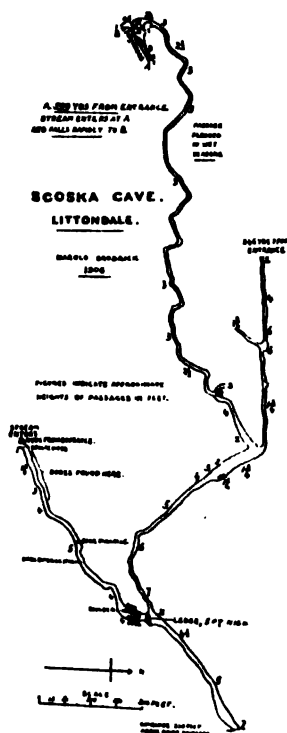


FIG. 1.

the roof is between 20 and 24 inches in height, from which, on the occasion of the first exploration, depended a regular forest of stalactites, many of which had to be broken off to afford a passage. Judging by their length and size, some of these must have taken centuries to form, so that it is clear this part of the cave has lain undisturbed for hundreds of years, and that the bones got into the position in which they were found before the stalactites were formed. All the bones belong to one person.

The main passage to the right has been followed to a point over a

quarter of a mile from the entrance, but has revealed nothing of interest. That the cave was ever used for burial purposes has not been borne out by any further discovery; whilst the fact that the remains were found so far from the entrance negatives the idea that the body was buried there in the normal course of events. As will be stated later, the remains have been identified as those of a woman belonging to the Bronze Age. Now, it is known that the people of this period disposed of their dead by cremation and not by burial, except in the case of their chiefs (being men), who were laid in stone cists under tumuli. Again, the examination of the skull has revealed the presence of a jagged hole just above the right mastoid process, which might have been caused by some rude weapon, such as a stone axe or spear. A wound of such a nature would not be immediately fatal, so that I have conjectured the history to be possibly this: that this woman, under the stress of some strong emotion, such as fear of a recent and pursuing assailant, entered the cave to hide herself, and, crawling to its innermost recesses, there succumbed either to her injuries or to starvation. Such a conjecture at any rate offers a possible explanation of the position in which the bones were found.

From a consideration of the measurements and condition of the skull and other bones the following conclusions have been arrived at:—The skeleton is that of a woman, whose height was about 5 feet 3 inches. The skull is of the brachycephalic or broad-headed type. It is probable that she lived towards the termination of the Bronze Age, although, as the earlier races persisted for a long time in the Craven Highlands, it is possible that she can be ascribed only to the end of the Roman occupation of Britain. At any rate, the period when she lived must be conjectured as being somewhere between 1500 and 2000 years ago. Against this statement that she belonged to the Bronze Age is the fact that no bronze ornaments have been found in association with the skeleton; this may be accounted for by their having corroded away by the action of the water, or being buried in the stalagmite which covers the floor of the cave. The general appearance of the skull is compatible with this theory, which is also strengthened by the shape of the femur, more particularly in its upper part. This is so peculiar, and corresponds so closely with that of other prehistoric bones found elsewhere, that I think the antiquity of the skeleton is indubitable.

THE SKULL. (Fig. 2.)

Measurements.—Length, 168 mm.; breadth, 138 mm.; height, 129 mm.; cephalic index, 82; vertical index, 76; cubical capacity, 1420 c.c.; mesocephalic.

The average cubical capacity of the modern European female is 1378 c.c.

From its general appearance the skull is obviously female; the mastoid processes are small, whilst the frontal sinuses and superciliary ridges are diminutive and project but little. One noticeable feature is the condition of the teeth. These are all present in the upper jaw, with the exception of the two back molars, which evidently fell out subsequent to death. The lower jaw has unfortunately not yet been found. All the teeth show signs of considerable attrition, being worn flat, with the loss of the enamel in the



FIG. 2.

molars; this condition has probably been caused by eating corn ground between grit-stones, the grit being left in the flour. Many of these grit-stone querns or grindstones have been found in the Craven Highlands. The dental margin is saddle-shaped, and the palate high-arched and contracted. The front teeth project forward prominently, and the set of the nasal bones is almost at right angles to the face; so that, judged by our standards, her appearance would not be attractive. The forehead would be very low. The nasal septum is deflected to the right, and there is consequently marked hypertrophy of the left turbinal.

The age of the woman may be deduced within definite limits by a consideration of the condition of certain of the cranial sutures. Thus the

junction of the basi-occipital with the sphenoid is obliterated, and therefore her age was over twenty-four; but as the interparietal or sagittal suture shows no sign of commencing obliteration, her age was certainly under forty-five. But the worn condition of the back teeth would indicate that the latter period of life is the more probable, so that we must take it that her age was somewhere about forty, or even possibly younger, as the incisors are but little worn away.

Just above the right mastoid process (fig. 3) there is a small irregularly shaped hole penetrating the outer table of the skull only. When the skull was first found, all the right side was covered by a thick layer of adherent



FIG. 3.

stalagmite, whose removal was a work of some difficulty. In doing this the edges of the hole have been scraped, so that it now bears a somewhat artificial appearance. In my opinion, however, this hole was ante-mortem and not post-mortem, as I fail to see how it could have been brought about since death, considering the situation wherein the skeleton has lain for so long a period.

THE FEMUR (LEFT). (Fig. 4.)

This bone is quite perfect and is but little stained with peat. When discovered, it was deeply embedded in stalagmite, only a small portion of the lower end being visible. That it belongs to the female sex may be deduced from two facts: firstly, the angle of the neck approaches more nearly a right angle than an obtuse; and secondly, when held upright on a flat surface, the extreme degree of obliquity which the bone presents in

order to allow for the increase in width of the pelvis. The linea aspera is very prominent, and all the other muscular attachments are strongly marked. The shaft of the bone, especially in the upper part, is unusually flattened, and lacks its wonted cylindrical shape, while the lower portion is also somewhat expanded. The popliteal triangle is remarkably smooth and sharply defined. The adductor tubercle is prominent.

The shape of the shaft seems to correspond closely with that of one



FIG. 4.

described in Boyd Dawkins' *Cave Hunting* (p. 172), which came from the sepulchral cave at Perthi-Chwareu. Of this latter, the chief peculiarity was the compression of the shaft in the upper part.

Another point of interest about this femur is that it is in the condition known as "pilastered." If it be laid flat on a plane surface alongside a modern femur, it is at once apparent that the forward convexity of the shaft is increased, whilst the backward concavity is exaggerated. The bone is a flanged pillar having its solid "rib," the linea aspera, on the concave or compression side, and its wide front on the convex or tension side.

The length of the bone is 16.5 inches, or 420 mm., whilst the least cir-

cumference of the shaft is 3.25 inches, or 82 mm.; so that the perimetral index, *i.e.* $\frac{\text{least circumference}}{\text{length}} \times 100$, is 17.5. The perimetral index of a modern femur selected at random as a control proved to be 19.1.

THE TIBIÆ AND FIBULÆ.

Of the bones forming the lower part of the legs, both the tibiæ and the fibulæ are present, though the patellæ are missing. The former offer several features of great interest. Both are deeply stained with peat, and, save for a fracture across the middle of the shaft of the right one, are in good condition.

The left tibia, which is the more perfect of the two, measures in length 14 inches, or 355 mm., the measurement being taken from the summit of the spinous process to the point of the internal malleolus; this would give her height as 5 feet 3 inches, the tibia of Europeans being about 22.1 per cent. of the stature.

The sex is again indicated by the shape of the bone, which has a slight oblique direction downwards and outwards, in order to compensate for the oblique direction of the femur inwards, caused by the increased width of the pelvis.

Associated with a "pilastered" femur, one would naturally expect to find the tibiæ to be "platynemic," and to show a diminished degree of torsion of the shaft, and such indeed is the case. Both tibiæ are markedly platynemic; *i.e.* they present a flattening or lateral compression of the shaft; the oblique ridge is prominent behind, giving to the bone a two-edged appearance. This condition of platynemia is commonly met with in prehistoric tibiæ, and is to be found in primitive races existing at the present day, such as the Bush races of South Africa. The explanation which has been offered for this particular shape of bone — one which is also met with in the anthropoid apes — is a connection with the greater freedom of motion and general adaptability of the toes and feet enjoyed by those people whose lower limbs have not been subjected to the confinement of shoes and other coverings, and who, at the same time, have been compelled to lead an active existence in a rude, rugged, or mountainous country, where the exigencies of the chase would demand the utmost agility in climbing, and otherwise.

Another point of interest in the shape of the bones, connected with the habits of these early races, is the formation of the external condyle. On comparison with a modern tibia, it is found to be much more convex and prominent, whilst the articular surface for the condyle of the femur is

more deeply notched. This convexity is evidently connected with the frequent strong flexure of the knee-joint, such as occurs in the attitude of squatting. This position of the body also causes a strong flexion of the feet at the ankle-joint, and brings about an articulation between the astragalus and the tip of the internal malleolus, which shows itself by the formation of an articular facet on the neck of the astragalus. This particular astragalo-tibial articulation rarely occurs in the higher races; but parallel modifications of both the upper and lower ends of the tibia occur in the anthropoids and among the lower apes.

The length of the left tibia, as already stated, is 14 inches, whilst the least circumference is 2.75 inches, so that the perimetral index is 19.6.

The latitudinal index, a figure expressing the relationship that the transverse diameter of the shaft bears to the antero-posterior, taken at the point where the popliteal line terminates at the inner border of the bone, is found to be 64 (A.P. $\frac{1}{2}$, T. 1 in.). This index is employed to indicate the actual amount of compression or flattening of the shaft as compared with the normal form, which may be taken for the ordinary English tibiae as 73.

The fibulae, both of which are broken (the left in five pieces), do not call for any detailed description.

OTHER BONES.

Right Clavicle.—In the female this bone is less curved, more slender, and smoother, while the ridges for muscular attachment are but faintly marked. This clavicle obviously is female.

It measures $5\frac{1}{2}$ inches, or 140 mm., in length, and is stained black.

Left Humerus.—This bone is quite perfect, and is also deeply stained. The muscular attachments are but poorly marked, so that the shaft is remarkably smooth. There is no sign of any perforation in the olecranon fossa, nor is there a supra-condyloid process.

It measures in length $12\frac{1}{2}$ inches, or 316 mm. Now, the average length of the adult female humerus is 320 mm., and that of the male 355 mm., so that this humerus is about the normal length for a woman. Its proportion to the stature averages 19.9 per cent. in European females, so that from that basis her height was 62.8 inches, practically 63 inches, or 5 feet 3 inches—a figure identical with that obtained from the tibia.

The least circumference is 2.25 inches, giving a perimetral index of 18.

Right Radius.—This is the only one of the bones of the fore-arm which is perfect. It is stained deep black like the others, and has ill-defined muscular attachments.

It measures in length 9 inches, or 230 mm. The average female radius measures 220 mm., and the male 250 mm., so that this one is rather above the average length. Its proportion to the stature is stated to be 14·3 per cent., so that her height, as calculated on that basis, would be 62·9 inches, practically 63 inches, or 5 feet 3 inches, as before.

Concerning the rest of the skeleton there is nothing special to be noted.



FIG. 5.

CONCLUSION.

In conclusion, then, from a consideration of the general configuration of the skeleton, more especially the leg-bones, we are led to the probability that this woman belonged to a race of people who depended for their livelihood upon their agility in the chase, and for their safety upon their swiftness in evading their enemies; that, with their prehensile feet and active limbs, unencumbered with clothing, they were able to travel rapidly and easily over rough and mountainous country; that their habitual posture when at rest was that adopted by all primitive races, and by many even at the present day, viz. the position known as squatting; that these habits have moulded the bones into certain definite shapes, which

230 Prehistoric Skeleton found in a Cave in Littondale, Yorkshire

are easily recognisable, and are still to be met with in the lower races of the present time.

CATALOGUE AND MEASUREMENTS OF BONES (Fig. 5.)

<i>Left femur</i> , 420 mm. or 16·5 in.	<i>Left tibia</i> , 355 mm. or 14 in.
<i>Left fibula</i> , 340 mm. or 13½ in.	<i>Right tibia</i> , 350 mm. or 13¾ in.
<i>Right fibula</i> , 340 mm. or 13½ in.	<i>Right astragalus</i> , 1st and 3rd Metatarsal.
<i>Right clavicle</i> , 140 mm. or 5½ in.	<i>Right radius</i> , 230 mm. or 9 in.
<i>Right ulna</i> , 232 mm. or 9¼ in.	<i>Left humerus</i> , 316 mm. or 12½ in.
<i>Left ulna</i> , 215 mm. or 8¼ in.	<i>Left radius</i> , 10 mm. or 4 in. of the shaft.

Portions of the left side of the pelvis, including the acetabulum, the tuberosity of the ischium, the body of the pubes, and the commencement of the crest of the ilium.

Vertebrae.—4th or 5th cervical, 5th or 6th dorsal, 11th dorsal, 12th dorsal, 5th lumbar, another lumbar in fragments.

Ribs.—Left 1st, right 12th, several other portions (fragments).

ADDENDUM.

Since writing the above, I am glad to announce that several other portions of the skeleton have been found, viz.: the right half of the lower jaw, with most of the teeth *in situ*; the atlas; the second left metacarpal; a middle phalanx.

The credit of this further discovery belongs to Mr J. B. Barnes of Birkdale, Lancs., to whom we are indebted for the major portion of the find. I wish to express my thanks to him for allowing me to make use of the bones for the purposes of this paper, as well as to several fellow-members of the Yorkshire Ramblers' Club who have assisted me in the search on various occasions.

ABNORMALITIES OF THE PYRAMIDAL TRACTS.

By G. ELLIOT SMITH, F.R.S.

THIS note refers to a series of examples of the aberrant circumolivary bundle derived from the pyramidal tract, to which attention had previously been called by the author in a preliminary Note published in the *Review of Neurology and Psychiatry*, May 1904. More than sixty examples of this aberrant track have been seen by the author: in more than 90 per cent. of these cases the bundle was found only on the left side, in only two cases on the right side only, and in the rest on both sides. The fibres are distributed in the floor of the fourth ventricle, and in two cases some of the fibres proceeded down the posterior columns of the spinal cord. In most cases some of the fibres lose themselves in the restiform bodies and become indistinguishable from the mass of fibres going to the cerebellum.

THE CAUSATION OF THE SYMMETRICAL THINNING OF
THE PARIETAL BONES IN ANCIENT EGYPTIANS. By
G. ELLIOT SMITH, F.R.S.

No satisfactory explanation has yet been given of the mode of causation of the curious symmetrical thinning of the parietal bones described by Maier (*Virchow's Archiv*, vii. 336), and subsequently by Sir George Humphrey (*The Human Skeleton*, 1858, pp. 242-243) and others. Sir George Humphrey states that "the exact symmetry, the similarity of the deficiency in the several cases, and the absence of any trace of disease, render it most probable that the conformation was congenital." Maier, however, and the few recent writers (*e.g.* Ziegler, *Text-Book of Special Pathological Anatomy*, transl. MacAlister and Cattell, 1896, sections i.-viii., p. 143), who refer to this condition, regard it as a senile atrophy.

In contrast to the rarity of the occurrence of this peculiar conformation in European crania—Sir George Humphrey was able to find only six examples in European museums, one in Cambridge, four in Paris, and one in Berlin—it is very common in ancient Egyptian cemeteries. It is produced by a gradual wearing away of the outer table of the cranium, until in many cases the diploe is reached, and even the inner table may become eroded. The causal factor invariably operates from the outside, and the shape of the cranial cavity is not affected. The process of erosion never attacks those parts of the skull which are covered by muscle, and a ring of bone (about a centimetre in diameter) around each parietal foramen is almost invariably spared. It is clearly due to some agent exerting *continuous* pressure on the cranial vault where this is unprotected by muscle, and the pressure may act by interfering with the blood supply of the bone. It cannot be congenital, because the examination of a large series of cases shows that it is certainly the result of the erosion of a properly developed cranial wall; and further, in more than seventy examples of this condition, there is not a single instance of its occurrence in an individual under 25, or perhaps even 30, years of age.

It cannot, however, be regarded as a senile change, because it frequently occurs in crania where the coronal sagittal and lambdoid sutures show no trace of closing. Nor has it any relationship to sex, occurring as it does in both men and women.

In the collection of ancient Egyptian crania its distribution is peculiar. In large collections of crania of the most archaic period, I have not found a single example of this peculiar thinning, nor have I found it in any skulls later than the New Empire. It is only in the period between the fourth and nineteenth dynasties, and only in the upper classes—*i.e.* in the tombs of wealthy people—that this atrophy occurs. This cranial thinning, in other words, is only found in those people who were accustomed to wear wigs of enormous proportions and of great weight. It is, of course, impossible to state dogmatically that there is a causal relationship between these two facts; but it is highly suggestive of the origin and the frequency of this thinning in a particular class and at one definite period.

The modern Egyptian Fellahin women are accustomed to carry on their heads water-jars of enormous weight: but I have never met with a single case of thinning of the parietal bones in these people. It is *continuous* pressure of a lesser weight, and not the intermittent application of a great weight, that brings about the atrophy.

These observations could have been made only under very exceptional circumstances, *i.e.* when large series of *accurately dated* specimens were available. It has been my good fortune to have had such material, together with the accurate information, provided for me by the Hearst Egyptological Expedition of the University of California, whose work has been conducted by Dr George A. Reisner and Messrs A. M. Lythgoe and A. C. Mace, who have always given me their assistance in this work.

ON CERTAIN PECULIARITIES OF BRAINS LACKING A CORPUS
CALLOSUM. By G. ELLIOT SMITH, F.R.S.

THIS note is based upon the examination of the acallosal brains of two Fellahin women who, by a most extraordinary coincidence, died within a few hours of one another in the Kasr el Ainy Hospital in Cairo. One of these brains was very much smaller (950 grammes) and the other much bigger (1400 grammes, after being three days in a body preserved by intravascular injection of 10 per cent. formalin) than the average (1168 grammes) of one hundred Fellahin women's brains weighed by me. The histological examination of these brains is being made by Dr R. G. White, Assistant Professor of Pathology in Cairo, who has permitted me to use some of the data already elicited.

The long series of elaborate and almost exhaustive studies of human brains lacking a corpus callosum that have been published within the last few years—Arturo Banchi, in a most valuable memoir, "*Studio anatomico di un cervello senza corpo calloso*" (*Archivio italiano di Anatomia e di Embriologia*, vol. iii., fasc. 3, 1904), gives a list of no less than sixty-seven memoirs on this subject—leaves little to be done toward the elucidation of the mere anatomy of the brain in such cases. The arrangement of the fornix system of fibres in these brains presents a Metatherian simplicity, and it was the results of the study of this system that I had intended to deal with in this note; but the researches of Probst, and especially Banchi, among many others, have quite forestalled all that I had to say on that subject.

One of the most constant distinctive features of brains without corpus callosum is a marked dilatation of the posterior cornu of the lateral ventricle and great thinning of its walls. This is probably the result of the freedom from the restraining influence of the forceps major of the corpus callosum on the backward expansion of the hemisphere.

One of the most instructive features of these specimens is the demonstration—by defect—of the influence exerted in the normal brain by the backward extension of the corpus callosum on the calcarine and parieto-occipital group of furrows. In acallosal brains the gyrus cuneus comes to the surface; the two main sulci of the parieto-occipital group (the intermediate furrow having disappeared) are widely separated by a superficial

gyrus; the simple calcarine sulcus is accompanied by two pairs of parallel furrows—the superior and inferior limiting sulci of the area striata respectively above and below it; and the sulcus paramesialis occipitalis, and the posterior part of the collateral, which are respectively the superior and inferior limiting sulci of a parastriate area.

Thus we have a much simpler—almost diagrammatic—arrangement of the parieto-occipital furrows, which becomes considerably disturbed when, in the course of the development of the normal brain, the splenium of the corpus callosum pushes its way into their midst.

ASYMMETRY OF THE BRAIN AND SKULL.

By G. ELLIOT SMITH, F.R.S.

MANY writers have called attention to the asymmetry of the cranium, brain, and intracranial venous sinuses separately, but comparatively little work has yet been done to study the co-relation of these asymmetrical conditions the one to the other or to explain their origin.

One of the most striking points of contrast between the cranium of Man (and especially the higher races) and that of the apes (and to a less degree that of the black races) is the asymmetry of the former and the much closer approximation to perfect symmetry in the latter. The lack of symmetry of the cranium in Man is the result of the unequal development of homologous parts of the two cerebral hemispheres—especially the great parietal and frontal association areas. The result of the unequal development of the frontal areas is not only a greater fulness of one side of the frontal bone, but a displacement of one orbit, producing an asymmetry of shape and position of the orbits and their contents.

The greater size of the right parietal association area not only leads to greater prominence of the corresponding parietal bone and a relative shifting backward of the right parietal boss (already described by Gruffrida Ruggeri), but also indirectly explains (1) the usually greater extent of the *lateral part* of the left visual cortex and the retention of a more pithecoïd form in the left hemisphere; (2) the greater prominence of the occipital pole of the left hemisphere and occipital squama (Tedeschi, "*Studi sulla simmetria del Cranio*," *Atti della Società Romana di Antropologia*, vol. iv. Nos. 2, 3, 1897); and (3) why the larger lateral sinus, which receives the blood from the superior longitudinal sinus, is usually on the right side.

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A NEW TOPOGRAPHICAL SURVEY OF THE HUMAN CEREBRAL
CORTEX, BEING AN ACCOUNT OF THE DISTRIBUTION
OF THE ANATOMICALLY DISTINCT CORTICAL AREAS
AND THEIR RELATIONSHIP TO THE CEREBRAL SULCI.
By G. ELLIOT SMITH, M.A., M.D., Ch.M., F.R.S., *Professor of
Anatomy, Cairo.*

IN the last number of this Journal I called attention to the fact that by means of the naked-eye examination of sections of the fresh brain it is possible to recognise the differences in thickness and texture of various cortical areas, and so to map out the exact extent of each of the regions. In that communication I illustrated the method in its application to the visual areas of the cortex, which comprise the greater part of the so-called occipital "lobe" of the hemisphere. In the present memoir I propose to extend this survey to the whole of the surface of the cerebrum, and to present maps of the whole cortex, which I believe to be more complete and at the same time more exact than those obtained by the application of other more laborious methods. Nevertheless, the diagrams presented here are merely preliminary attempts at an adequate charting of the surface of the brain: in a series of further contributions to the consideration of this subject I propose to take up one by one each region of the cortex and discuss in much greater detail than the present sketch pretends to give the exact topography of each area and the wide range of variability and relationship to sulci which is found in every part of the human neopallium.

In my earlier communication I have insisted on the fact that in the process of folding of such a plastic material as cerebral cortex we find that as a rule sulci do not develop with mathematical precision at the exact boundary lines of adjoining areas or in the precise axis of any given territory. But while fully realising the accuracy of Professor Sherrington's observation that they "are not reliable as landmarks," we cannot be

blind to the fact that each one of the vast majority of the furrows on the surface of the hemisphere presents a definite causal relationship to some given cortical area (or areas). This relationship can only be properly appreciated when a large number of specimens have been studied, because the edge of a cortical area may extend beyond or may not reach as far as the floor of a sulcus, which the examination of a large series shows to be causally related to it, or, in fact, its real limiting sulcus; and in many cases it happens that by mere chance the edge of an area may coincide with a furrow, which might thus come to be regarded as its morphological boundary if a more extensive study had not revealed the fact that the relationship was merely fortuitous. It will be understood from these preliminary remarks that the accompanying diagrams are intended to embody the results of the examination of a very large series of specimens, and that in no single example is the exact condition represented in these schemata likely to be realised in every particular.

A vast amount of work has been devoted to the elucidation of the localisation of the cerebral cortex, but so far as I am aware, only two writers have ever attempted to present *complete* charts of the distribution of the various areas in the human brain.

As the result of a long series of investigations into the chronological order of the process of medullation of the various districts of the cortex and its subjacent white substance, Professor Flechsig has been able to construct complete maps of the surface of the human brain (1, 2, and 3). A series of these diagrams will be found in his work, *Einige Bemerkungen über die Untersuchungsmethoden der Grosshirnrinde, insbesondere des Menschen* (3).

Another pair of most instructive maps compiled by Flechsig (2) are to be found in the sixth edition of Halliburton's *Handbook of Physiology* (1904, p. 696); the originals of these are not available to me at present (2).

Dr Alfred Campbell has recently published maps of the human cerebral cortex based on histological studies (4).

Many other investigators, such as Bolton, Vogt, and Brodmann, have recently studied the histological localisation of certain parts of the cortex cerebri of man and other mammals (see especially 5).

At the outset it is advisable to make it perfectly clear that no claim is made for this method other than that of enabling us to map out such areas as present contrasts in thickness, texture, and colouration to the naked eye. It is not pretended or in any way assumed that such contrasts in appearance necessarily imply physiological differences or even essential distinctions in histological constitution. Moreover, I am not unmindful of the fact that in basing this gross means of localisation on (essentially) one factor in the constitution of the cortex, *i.e.* the arrangement of the intra-

cortical medullary matter, we are apt to overlook real differences and be deceived by spurious resemblances. Nevertheless the fact remains that there are obvious macroscopic distinctive features of the various cortical areas: these I have attempted to map out. The fact that most of these areas have precise relations to various stable sulci, and that their distribution agrees so nearly with those mapped out by Flechsig, using another method, seem to point to the condition that we are dealing with truly localised cortical areas which expand at unequal rates in the course of their development, and are, therefore, presumably of different function.

And when I add that by the grosser method it is possible to do the

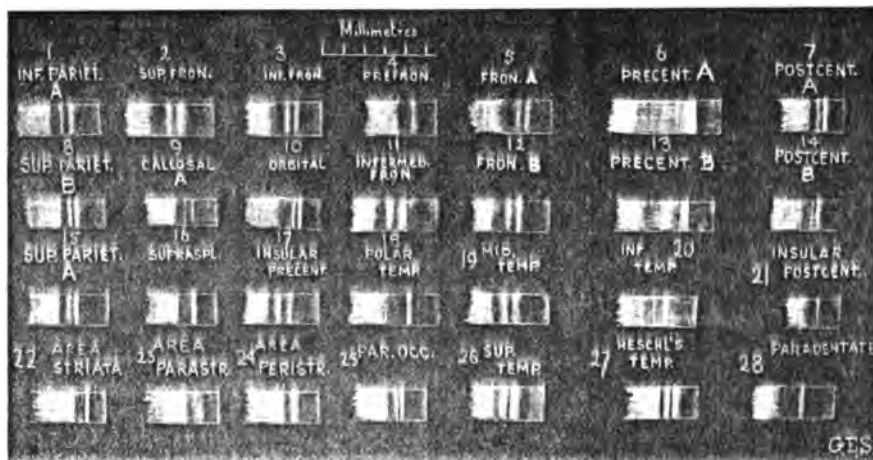


FIG. 1.

mere mapping out of a hemisphere in one hour, which would take an immeasurably longer time to do by either of the other methods, we can appreciate how useful this method becomes when it is necessary to examine large series of specimens to determine the relationships of sulci and localised areas. I have insisted on the relationship to the furrows so constantly because this research was begun with the intention of studying the meaning and origin of sulci; but in the course of the work the more striking results bearing on the localisation of the cortex have relegated the problem of explaining the sulci to a secondary place.

THE NEOPALLIAL AREAS AND SULCI.

If a fresh cerebral hemisphere be taken and incisions be made in every part of it by means of a scalpel, more than thirty different types of cortex

can be distinguished by the naked eye in the neopallium in addition to the various parts of the rhinencephalon. Twenty-eight of these types of cortex are represented in a semi-diagrammatic form in the accompanying figure (fig. 1), which is a photograph of a series of drawings made on a blackboard from a fresh brain—in all cases the surface is on the right side and the medullary matter on the left: every slice was accurately drawn to scale, and the attempt was made to represent the features of each region without any pronounced exaggeration. In the photograph the features have become intensified, so that the drawing seems more diagrammatic than the original chalk sketches were intended to be. This exaggeration is useful if it serves to fix the reader's attention on those delicate intracortical bands which anyone can see for himself in a fresh brain once he has been reminded of their existence and their general characters. The most distinct of all these bands is, of course, the stria Gennari found in the visual cortex (fig. 1, No. 22); but the others can be recognised with more or less ease after a little experience. Perhaps the greatest contrast is found in the upper part of the sulcus centralis, the anterior wall of which consists of the thickest cortex (almost 4 mm.) with a maximum amount of white matter widely diffused (fig. 1, No. 6), whereas its posterior wall is composed of one of the thinnest cortical areas (often only 1.5 mm. thick) with a pair of narrow, compact, white bands (fig. 1, No. 7).

There is a very widespread belief that the characters of one area merge gradually and imperceptibly into those of the neighbouring areas, but this is entirely mistaken. The changes in structure occur with the utmost abruptness, so that it is possible to determine with absolute precision the exact boundaries of each area. If the reader needs convincing of the accuracy of this statement let him cut a fresh brain at right angles to the calcarine, intraparietal (any part), central, inferior frontal, or parallel sulci, and he will find all the confirmation that is necessary. The very greatest variations in the distinctness of the intracortical bands will be found in different specimens. Many factors determine this variability—age, race, cause of death, the time that has elapsed after death, and other as yet unknown reasons. The bands are not all present in the form represented in the diagram (fig. 1), excepting in adults. In a new-born child all the cortical areas are uniformly grey and translucent, but a milky whiteness is visible in the subcortical matter around the central, calcarine, and superior temporal sulci. But it is not until long afterward that the intracortical medullary bands become recognisable to the naked eye in fresh, unstained sections. In a child of eight *years* the picture of the cortex obtained by the macroscopic examination of the fresh brain corresponds to that obtained by Flechsig in stained sections of the brain a month after birth. By

twelve years of age all of the areas contain intracortical bands visible to the unaided eye: but many of these bands are (relatively to the rest) much fainter than they are in the adult, and all of them are less dense. As age advances the bands become denser and more pronounced, as we should expect from the results of Kacs' researches. So far as the mere chronological order of development is concerned—*i.e.* without being able to give the *actual dates* of the appearance of fibres—one can verify Flechsig's results by the examination of sections made with a scalpel in fresh brains of children ranging from the time of birth up to twelve years of age. This method has been of great service during the course of this investigation in enabling me to distinguish adjoining areas of similar appearance in the adult brain. But for the main purposes of this research I have employed the brains of adults of more than twenty years of age.

As a general rule I have found the brains of negroes more useful than those of other races. The cortex of the negro is often distinctly brown, and this enhances the contrast to the white bands.

Various pathological conditions, both general and local, profoundly affect the distinctness of the features of the cortex. Profound anæmia, such as occurs in ankylostomiasis, so blanches the grey matter that it is often quite impossible to see any band except the line of Gennari.

Within two or three hours after death the cortex has quite a translucent appearance, and the white bands stand out with extraordinary prominence. As the body cools the grey matter becomes cloudy and the bands more and more blurred and ill-defined.

The intracortical bands are usually quite distinct in specimens which have been fixed *in situ* by intravascular injections of formalin. In the course of this investigation such material obtained from the dissecting-rooms has been of the utmost value, because hardened specimens are so much easier to deal with and to make photographs and drawings from than fresh specimens are. Brains fixed and preserved in a bath of formalin are not nearly so satisfactory as those obtained from bodies treated by intravascular injection: in the former the cortex becomes "cloudy," whereas in the latter it retains more of the translucency of fresh material. In many specimens that have been kept in Müller's fluid, even for long periods, the bands are quite distinct. And in sections (cut by a microtome) of material fixed in almost any manner, when examined either in water or Farrant's solution, the cortical lamination is quite obvious, and, as a rule, the contrasts are greater and more striking than in sections stained by any method. Apart from the visual area (which was examined in more than a thousand hemispheres), this work is based upon the study of more than two hundred adult hemispheres.

This account is nothing more than a mere preliminary sketch to give some idea of the results to be obtained by the simple means of naked-eye examination of material cut with a scalpel. No attempt has been made in this communication to collate these results systematically and completely with those obtained by other methods of research.

This can only be done with any satisfaction when results obtained by both methods have been much more fully elaborated than is the case at present.

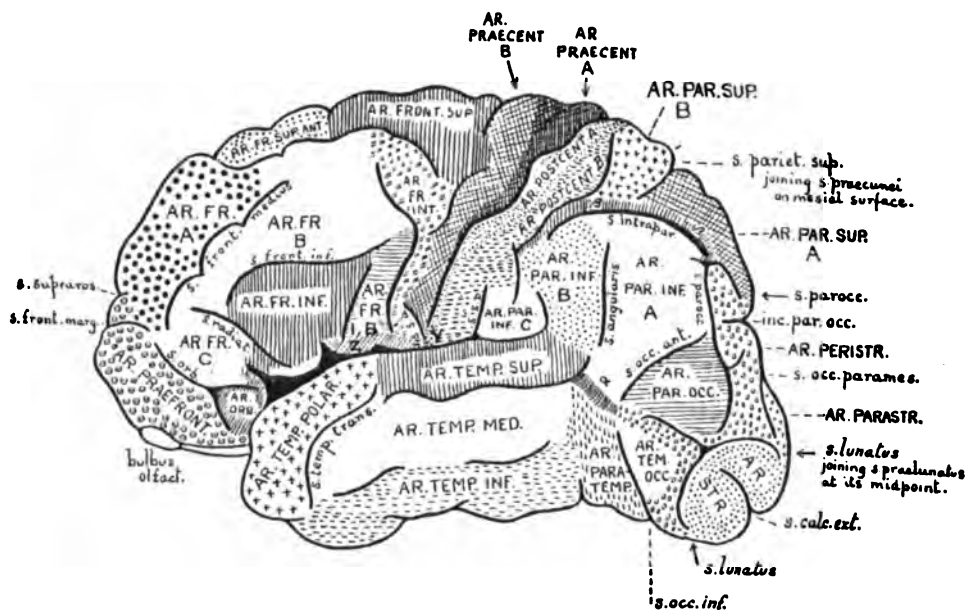


FIG. 2.

The Visuo-Auditory Band.

In my previous communication on the visual area I have described a forwardly projecting tongue of *area peristriata* which becomes folded in its long axis to form the *sulcus prelunatus* (mihi)—a furrow identical with that called *sulcus occipitalis lateralis* by most writers. From the anterior end of this band a narrow strip of cortex (sometimes no more than one centimetre in width) extends forward (fig. 2, *a*) as far as the upper end of the *sulcus temporalis superior*, in the floor of which it becomes continuous with the *area temporalis superior* (fig. 2, AR. TEMP. SUP.), which is the "audito-psyche area" of Campbell and other writers. This strip *a*, which I shall call the "visuo-auditory band," serves as a narrow connecting

bridge between the *area peristriata*, which is the "visuo-psychic area" of Bolton and others, and the "audito-psychic area," so that it links together the outlying parts of those regions of the cortex which are given up to the functions of sight and hearing. This attenuated band is all that is left of the extensive bond of union between these two areas which in the lowlier mammals have co-extensive borders: in man and to a less extent in the apes the great development of the inferior parietal area (fig. 2, AR. PAR. INF.) above it and the temporal areas (fig. 2, AR. TEMP. MED.) below it have pushed these two parts asunder, leaving this narrow connecting bridge. In support of this hypothesis of the primitive nature of the band *a* I might call attention to the fact (which Flechsig has clearly established [3, Taf. II., fig. 4]) of its early medullation. In appearance the cortex of the visuo-auditory band closely resembles that of the *area peristriata* (fig. 1, No. 24) from which it is often quite indistinguishable. In other cases an indistinct doubling of the line of Baillarger occurs, so that it resembles the *area parieto-occipitalis* (fig. 2, AR. PAR. OCC., and fig. 1, No. 25).

It very frequently happens that the visuo-auditory band becomes folded in its long axis to form a horizontal sulcus which may join the *sulcus occipitalis lateralis*. Although this furrow is much more often present than absent, it has not yet received a distinguishing name, so far as I am aware. It occupies a position (fig. 2, *a*) which is seen to be the natural boundary line between the parietal and temporal areas: hence it might appropriately be called the "*sulcus temporo-parietalis*."

The whole of the area between the *sulcus occipitalis lateralis* (i.e. *prælnatus*) and the *sulcus occipitalis inferior* is often occupied by a cortical area indistinguishable from and continuous with the *area peristriata*; but part of this region (marked "AR. TEM. OCC." in fig. 2) occasionally exhibits a faint doubling of the line of Baillarger, which calls for its separation from that area. I have called it the "*area temporo-occipitalis*." In position and structure it is in many respects analogous to the *area parieto-occipitalis* (fig. 2, AR. PAR. OCC., and fig. 1, No. 25). The latter area is bounded in front by the *sulcus occipitalis anterior* (fig. 2, *s. occ. ant.*) and above (or behind) by the *sulcus paroccipitalis* (fig. 2, *s. parocc.*), which is the *ramus occipitalis* of the *sulcus intraparietalis*.

It often happens (especially in the brains of lowly human races, such as negroes and aboriginal Australians, and in the anthropoid apes) that the *sulcus occipitalis anterior*, together with the *sulcus occipitalis inferior*,¹

¹ Most writers who have within recent years described the brain in the higher apes have confused the *sulcus occipitalis inferior* with the *sulcus occipitalis lateralis* (*prælnatus*). As the latter is usually absent in the apes, the suggestion implied in this mistaken application of terms is insidiously misleading.

those in the superior lobule are denser and closer together than those of the inferior lobule.

The superior parietal lobule is crossed transversely by the *sulcus parietalis superior* on the dorsal surface and the *sulcus precuneus* on its mesial surface, the two furrows being often confluent. In most specimens I have found it quite impossible to distinguish the cortex of the area in front of these furrows (figs. 2 and 3, AR. PAR. SUP. B) from that placed behind them (AR. PAR. SUP. A): but it often happens that there is a distinct difference in the texture of the two parts (compare Nos. 8 and 15, fig. 1), the lines of Baillarger being somewhat narrower and denser in the *area parietalis superior anterior* (B) than in the *area parietalis superior posterior* (A). I am confirmed in drawing this distinction by the results of my examination of the brains of children, and by the definite evidence of the same nature which Flechsig has brought forward (β , Tafel II., figs. 3 and 4) by demonstrating that the anterior (B) district (his 16) becomes medullated some time earlier than the posterior (A) district (his 21).

There is another feature of this region brought to light by Flechsig which can be most clearly confirmed by the macroscopic examination of fresh sections of the adult brain. If a cut be made into the parietal region at right angles to the intraparietal sulcus, the lines of Baillarger in the superior parietal lobule will be found to become suddenly intensified (i.e. become denser and whiter) about 2 or 3 mm. from the upper lip of the sulcus, and this intensification is continued exactly to the bottom of the furrow. Flechsig has shown that this patch becomes medullated much earlier than the rest of the parietal region (β , Tafel II., fig. 3, No. 13). He has not shown that this band containing the intensified lines of Baillarger can be traced backward into continuity with the visual area in the floor of the *sulcus parietooccipitalis* and forward into continuity with the *area postcentralis* (fig. 2, $\beta\beta$), that, in fact, it is a "visuo-sensory band" exactly analogous to the "visuo-auditory band" (α) of which I have spoken in the preceding pages. It is the attenuated fragment of that extensive connection between the visual and sensory areas of the brain which has remained after these areas have been pushed apart by the great expansion of the parietal areas.

In the great majority of cases I have found the large and important inferior parietal lobule composed of a cortex of uniform characters, if we exclude the small antero-inferior corner (fig. 2, AR. PAR. INF. C) which perhaps ought not to be considered as a part of the lobule. The rest of the lobule is almost invariably subdivided into two parts by the *sulcus angularis* (which many writers call *ramus ascendens sulc. temp. superioris*), and in many cases the lines of Baillarger are more distinct in the area behind this furrow (fig. 2, AR. PAR. INF. A) than they are in front (AR. PAR. INF. B).

The area that lies immediately above the posterior end of the fissure of Sylvius, between the upturned end of the latter and the *sulcus subcentralis posterior* (fig. 2, *s.s.p.*), presents the same general features as the rest of the parietal region, but it (fig. 2, AR. PAR. INF. C) is thinner and its lines of Baillarger denser than those of the rest of the inferior parietal lobule. As Flechsig has shown, it becomes medullated long before the rest of the inferior parietal lobule. For the sake of conciseness I shall use the name "*area parasyllvia*" (in reference to its relation to the tail of the Sylvian fissure) for this area C (AR. PAR. INF. C). The anatomy of the regions around it presents many difficulties, to the consideration of which I shall return after studying the central convolutions.

The Central Convolutions.

Under this title are included the *area præcentralis* (subdivided into two parts, A and B), the *area postcentralis* (also divided into two parts, A and B), the continuation of these into the paracentral lobule and certain modifications of these formations at the two extremities of the convolutions (fig. 2, Y; fig. 3, X).

The structure of the two walls of the *sulcus centralis* forms a most striking contrast (fig. 1, Nos. 6 and 7).

The anterior wall of the sulcus in the upper (mesial) part of its extent is formed of cortex almost 4 mm. thick, which is so very rich in medullary matter that the inner two-thirds of its thickness is often uniformly pallid, and the line of demarcation between it and the white matter of the hemisphere is not so sharply defined as it is in other regions of the cortex (fig. 1, No. 6). The outer edge of the intracortical medullary matter is always denser than the rest, and sometimes two or even three faint bands can be seen in the cortex (fig. 1, No. 6). As the cortex is traced forward out of the sulcus into the exposed surface of the præcentral convolution the diffuse paleness gives place to a definite pair of lines of Baillarger, the inner of which is very broad and diffuse (fig. 1, No. 13). This is the *area præcentralis B*. The distribution of these areas is shown in the diagrams (figs. 2 and 3). As these areas are traced downward (toward the fissure of Sylvius), their outstanding features, as just described (and represented in fig. 1), become less pronounced, and the area A becomes restricted to the wall of the *sulcus centralis*. The naked-eye appearances of the præcentral areas is subject to a wide range of variation.

The *sulcus subcentralis anterior* (fig. 2, *s.s.a.*) is a limiting furrow of the præcentral area. The combined results of experimental, clinical, and histological evidence point to the fact that these præcentral areas

represent the "motor area"—the region that is responsive to electrical stimulation.

Like the præcentral area the postcentral is subdivisible into two or even three distinct regions, which in the main occupy respectively the posterior wall of the *sulcus centralis*, the crest of the postcentral convolution, and the anterior wall of the postcentral sulcus. For simplicity I have grouped the latter two in the one *area postcentralis B* in figs. 2 and 3, but the part represented in fig. 1, No. 14, is the type of the anterior wall of the postcentral sulcus.

On the mesial surface these two postcentral areas are prolonged as a crescentic band into the paracentral lobule (fig. 3). This band stops posteriorly exactly in the floor of the upturned end of the sulcus cinguli, and anteriorly in a fairly constant sulcus parallel to the latter, which serves as the line of separation between it and the motor area. This may be termed the "*sulcus paracentralis*," because it lies within the paracentral lobule. Below the motor area on the mesial surface (at the point marked X in fig. 3) the cortex seems to undergo a slight change in texture, the outer line of Baillarger (of the postcentral B type, fig. 1, No. 14) becoming markedly accentuated. This type of cortex lines the upper lip of the neighbouring part of the sulcus cinguli: exactly at the bottom of this furrow it gives place to another type distinguished by the presence of a pair of faint lines of Baillarger (fig. 1, 9). The distribution of this callosal area is shown in fig. 3 (AR. CALLOS. A).

At the lower end of the central sulcus the distribution of the various areas becomes so confused that it becomes an exceedingly difficult matter to interpret the appearances presented by sections of this region. This is rendered all the more difficult by the fact that the results obtained by the examination of one specimen do not accord with those that may be found in other cases. The *area postcentralis A* seems to be prolonged around the lower end of the *sulcus centralis* (at Y, fig. 2); but as it does so its bands of Baillarger become more attenuated, and this type of cortex (so far as can be judged by the naked eye) fringes the Sylvian fissure as far forward as the point marked Z in fig. 2.

I have already called attention to the presence of a curious cortex which lines the upper wall of the *sulcus intraparietalis* (fig. 2, β): when the latter sulcus approaches the *sulcus postcentralis* this area β occupies the little gyrus in the space between the two furrows (fig. 2); but in those cases in which the two sulci become confluent the visuo-sensory band (β) passes into the anterior wall of the inferior postcentral sulcus, and when it thus becomes brought into juxtaposition to the *area postcentralis B* it becomes difficult in many cases to distinguish these formations the one

from the other. So far as I can interpret the appearances seen in my specimens—but I must confess that I make these suggestions with some hesitancy—the *area postcentralis B* is always placed entirely in front of the *sulcus subcentralis posterior* (fig. 2, *s.s.p.*), but the area β (visuo-sensory band) sometimes does not reach as far as this sulcus, at other times attains its anterior wall, in other cases its posterior wall, or even invades the territory of the *area parietalis inferior C* (fig. 2).

A study of the results obtained by other writers does not help us to reach a satisfactory solution of this difficulty. Thus Campbell represents a downward prolongation of the superior parietal lobule passing *in front of the sulcus subcentralis posterior* in the human brain (4, Plate I.), but in the Chimpanzee's brain the *area postcentralis B* is shown extending back as far as this sulcus. This exactly agrees with the variations that I have found in the human brain.

In many specimens the cortex, that emerges from the lower end of the postcentral sulcus and extends downward to form the anterior lip of the *sulcus subcentralis posterior*, certainly differs in structure from all of the neighbouring areas—the inner line of Baillarger becomes so faint as to be hardly recognisable and the outer line becomes markedly intensified. This is a region in which histological investigation might be used with advantage to clear up the difficulty.

The Frontal Region.

As we pass forward from the thick præcentral cortex with its very diffuse pair of bands of Baillarger (fig. 1, No. 13), we come in succession to a series of areas in which the cortex becomes thinner and its bands more attenuated, until eventually we reach the thin præfrontal cortex (No. 4), in which one can see, as a rule, only one very pale band in an unusually clear and translucent grey substance.

The accurate mapping out of this area presents great difficulties, because the contrasts between adjoining areas are often exceedingly slight and at times quite impossible to detect. The diagrams of this region which I have made for this account (figs. 2 and 3) are, I believe, on the whole accurate representations of the average condition met with in a large series; but certain points may require revision at a later period.

In the area which Campbell (4, Plate I.) has allotted to the "intermediate præcentral" formation, there are found various types of cortex ranging from 3 mm. to only 1.75 mm. in thickness, and no less than five distinct localised districts of different structure can be recognised by naked-eye examination. These are the superior frontal (figs. 2 and 3, AR. FRONT. SUP., and fig. 1, No. 2), the intermediate frontal (AR. FR. INT. and No. 11), the

posterior inferior frontal (fig. 2, AR. FR. 1. B), the inferior frontal (AR. FR. INF. and No. 3), and finally the orbital (AR. ORB. and No. 10). The contrast between the narrow sharply-defined bands of the last three and the broad diffuse bands of the first two areas is obvious at a casual glance. The *area frontalis superior* is distinguished from the *area frontalis intermedia* by the fact that its bands are broader and more diffuse. [This contrast has not been sufficiently clearly depicted in fig. 1, which is, however, an accurate representation of a series of types taken from *one individual specimen*. In most specimens, however, the contrast is most marked.] These two areas are about 3 mm. thick, although the intermediate frontal is often a little thinner.

The inferior frontal area is about 2.25 mm. thick, *i.e.* about three-quarters the breadth of the intermediate and superior frontal areas. It contains much narrower bands of Baillarger, with sharper edges (fig. 1, No. 3), and the whole cortex is clearer and more translucent than the superior frontal. The dorsal boundary of this area is the *sulcus frontalis inferior*, its posterior boundary is the *sulcus diagonalis*, and its anterior boundary the *sulcus radiatus* of Eberstaller, although it must be admitted that its relations to these morphological boundaries is rarely, if ever, preserved with mathematical exactness.

The strip of cortex (fig. 2, AR. FR. 1. B), included between the *sulcus diagonalis* and the inferior præcentral sulcus, differs in structure from both neighbouring areas. It is thicker than the inferior frontal area, and its bands of Baillarger are less dense than those of the areas in front and behind it.

The *area orbitalis* (fig. 2, AR. ORB.) is limited in front by the two posterior limbs and the transverse portion of the orbital sulcus, and it extends as far back as the edge of the orbital operculum. At its lateral angle it becomes continuous with the inferior frontal area. It is composed of very thin cortex, often only 1.75 mm. thick, and it is distinguished by the presence of a pair of very narrow dense lines of Baillarger, placed so close together that they often have the appearance of forming one band (fig. 1, No. 10).

Flechsig has shown that it becomes medullated much earlier than most of the other frontal areas.

The *area frontalis superior anterior* is the strip of cortex included between the anterior part of the *sulcus frontalis superior* and the *sulcus cinguli* (figs. 2 and 3). In structure it resembles the *area frontalis* described below, but its bands of Baillarger are more distinct and also more diffuse.

The general features of the frontal area (fig. 1, No. 5) resemble those

of the other parts of the frontal region already described, but it is thinner (never more than 2.5 mm.), and its intracortical bands much more slender and less dense than those of the superior and intermediate frontal areas. It is divided into two main parts by the *sulcus frontalis medius* (fig. 2), which, in its typical form, is an obliquely-directed series of loops extending from the neighbouring ends of the *sulcus orbitalis* and the *sulcus fronto-orbitalis* of Wernicke upward toward the anterior end of the *sulcus frontalis superior*. The area *frontalis B*, placed behind the sulcus, is thicker (2.5 mm.) than the area *frontalis A* (2.0 mm.), which lies above and in front of the *sulcus medius*, and its bands are slightly denser and broader than those of the latter.

The area *frontalis C* resembles the area *B*, but in some cases it is thinner.

The anterior part of the *sulcus cinguli* is frequently separated from the rest of the furrow, and in such cases it is often prolonged obliquely upward and forward to form the boundary between the frontal and præfrontal areas (fig. 3, *S. suprarostralis*). That part of the marginal convolution, which is included between this suprarostal sulcus and the paracentral lobule, is often subdivided by a furrow which may be called "paracingular," into two parts (fig. 3, *S. paracing.*). The strip of cortex (AR. FR. D) which is placed between the cingular and paracingular sulci is often indistinguishable in structure from the parts adjoining it on the other side of the paracingular sulcus. However, that part of the gyrus which is placed below the anterior part of the area *frontalis superior* never resembles the latter, but may be considered as part of the area *frontalis superior anterior*; and the more anterior part of the convolution often differs from the frontal area in having the outer of its two lines of Baillarger distinctly intensified. The callosal convolution can be divided into a series of areas which are probably in some way influenced by the marginal areas, because they undergo changes similar to the frontal areas above them. The callosal area B (fig. 3) has much more delicate bands than the area A; and in the callosal area C, which surrounds the genu, the lines of Baillarger have become so faint that they are hardly visible at all: in the area D and the region marked with an asterisk (*)—the parolfactory area of His—no structure at all is visible in the cortex to the naked eye.

At the other end (*i.e.* near the splenium) of the callosal convolution there is a small wedge-shaped area (fig. 3, AR. PARASPL.). This area *parasplenialis* is exactly bounded by the *sulcus subparietalis*, which contains a very dense white band (fig. 1, No. 16).

The antero-inferior part of the frontal region is composed of the præfrontal area—a very thin clear cortex with a very fine single line (on

rare occasions doubled) of Baillarger (fig. 1, No. 4). On the mesial surface it is bounded by the suprarostal sulcus, *i.e.* the prolonged form of the anterior segment of the *sulcus cinguli* (fig. 3); and on the outer surface by the *sulcus orbitalis*. Although its upper boundary is always near the *sulcus fronto-marginalis* of Wernicke, it is only very rarely that it exactly

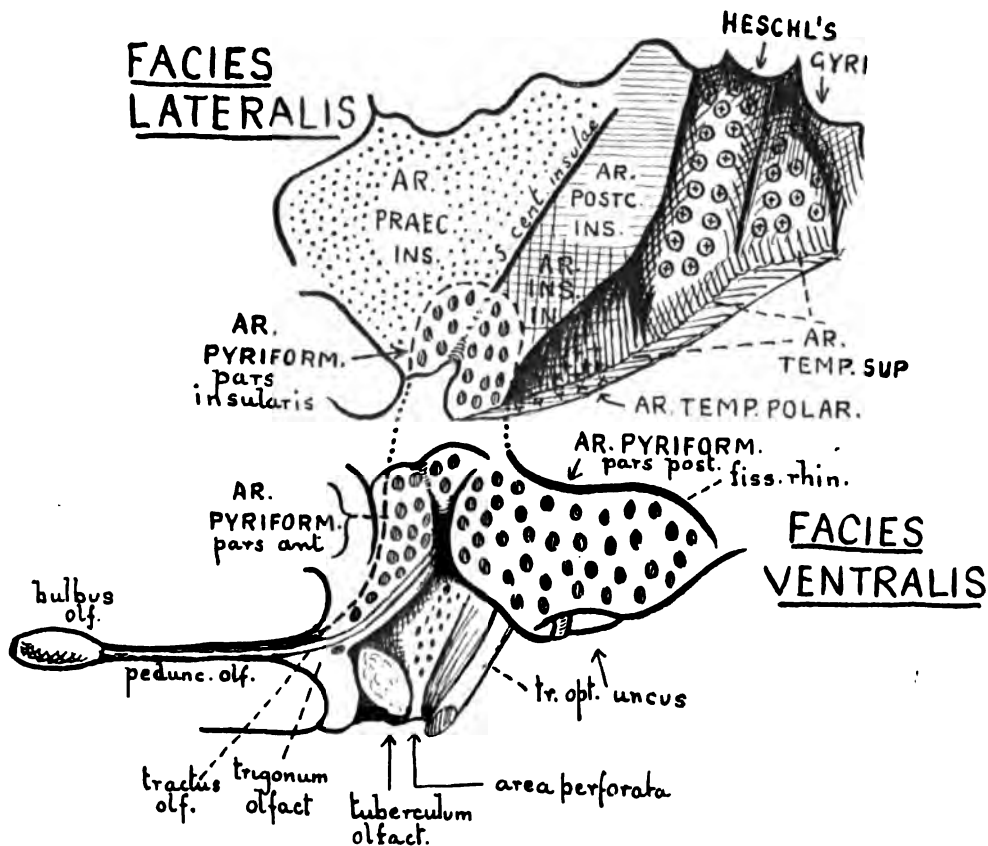


FIG. 4.

coincides with it. In most cases it just crosses this furrow to reach as far as the suprarostal sulcus (fig. 2, *S. supraros.*). The mesial part of the præfrontal area is subdivided by the *sulcus rostralis*, and the strip of cortex (fig. 3, AR. PRÆFRONT. B) which is placed between this furrow and the *sulcus cinguli* (*suprarostalis*) is distinguished from the rest by a pronounced intensification of the line of Baillarger.

That part of the *insula Reilii*, which is placed in front of the *sulcus*

centralis insula (fig. 4, AR. PRÆC. INS.), may be conveniently grouped with the frontal areas, because its appearance (fig. 1, No. 17) closely resembles the *area frontalis*, although its bands of Baillarger are very much more faintly marked. At the *sulcus limitans insula* the bands become more pronounced to form the inner lining of the frontal part of the opercula.

The Temporal Areas.

The two transverse gyri of Heschl, entirely buried in the fissure of Sylvius behind the insula (fig. 4), represent a sharply-defined anatomical area of thin cortex (1.75 mm.) occupied by two very dense bands (fig. 1, No. 27). All the available evidence—clinical, physiological, embryological, and anatomical—points to this region as the receptive area for impressions conveyed by the cochlear nerve.

The area surrounding it on the surface of the superior temporal convolution is composed of thicker cortex (fig. 1, No. 26) with less dense bands. Its distribution is shown in fig. 2 (AR. TEMP. SUP.). The area of insula adjoining Heschl's gyri is composed of thin translucent cortex with a single very delicate line (fig. 1, No. 21; fig. 4, AR. POSTC. INS.). The insular area below this (fig. 4, AR. INS. IN.) is composed of a thicker cortex, in which it is difficult to recognise any definite distinctive features.

The tip of the temporal lobe—both on its lateral, mesial, and insular aspects—is occupied by an area which I shall call "polar," because it occupies the pole of the temporal region (figs. 2, 3, and 4, AR. TEMP. POLAR.). It is a moderately thick, clear cortex with a single sharply-defined band (fig. 1, No. 18). It is often separated from the rest of the outer surface of the temporal region by a sulcus, which I have called "*temporalis transversus*" (fig. 2, *s. temp. trans.*). This is commonly regarded as part of the *sulcus temporalis superior*.

The rest of the outer surface of the temporal region is composed of an extensive district which in many brains presents a uniform appearance on section. But the upper half (fig. 2, AR. TEMP. MED.) will be found to be thicker (3.0 mm.) than the lower (2.5 mm.), and its bands stand out more clearly because there is less white matter in the surrounding cortex to blur the lines (fig. 1, Nos. 19 and 20).

Interposed between these two temporal convolutions (fig. 2, AR. TEMP. MED. and AR. TEMP. INF.) and the *sulcus occipitalis inferior* there is a narrow strip of thinner cortex with closely placed bands (fig. 2, AR. PARATEMP.). It passes obliquely forward on the tentorial surface (fig. 3).

On the mesial surface, the *area pyriformis* stops sharply opposite the tip of the acorn-like uncus (fig. 3). The strip of cortex (*gyrus paraden-*

tatus),¹ which extends upward from the pyriform area as far as the posterior end of the corpus callosum, is divisible (even on examination of the surface only) into two parts: the anterior strip (fig. 3, SUBIC. HIP.), covered with a thick white layer (*substantia reticularis alba Arnoldi*), is a mere appendage of the hippocampus; is, in fact, the *subiculum hippocampi*. The posterior part of the gyrus (fig. 3, AR. PARADENT.), which may be called *area paracaudata*, consists of a thin, clear cortex containing a very delicate, sharply-defined line (fig. 1, No. 28). As this formation is traced forward it merges into the *area temporalis polaris*, the cortex becoming thicker and the line denser (fig. 1, No. 18).

THE OLFACTORY PARTS OF THE HEMISPHERE.

Within the last few years so much has been written concerning the morphology of the parts of the cerebral hemisphere concerned with the sense of smell, that I am loath to return to the discussion of this region, which has so often engaged my attention in this Journal and elsewhere; but it seems necessary once more to emphasise some of the salient features of the rhinencephalon of the human brain, which has been so thoroughly and precisely described and so beautifully illustrated in Gustaf Retzius's monographs, because no other writer, so far as I am aware, has correctly identified even such fundamental features as the tuberculum olfactorium or the real boundaries of the pyriform lobe (fig. 4), the former being confused with the trigonum olfactorium and the latter with various adjoining areas. This is very difficult to understand when it is recalled that it is eleven years since Retzius indicated, in a manner that is quite convincing and final, the real nature and position of these parts of the human brain (*Das Menschenhirn*, 1896, Taf. xxxii.); and two years later he clinched the matter by instituting a detailed comparison of this region in the brain of man with that of other mammals ("Zur äusseren Morphologie des Riechhirns der Säugethiere und des Menschen," *Biologische Untersuchungen*, Bd. viii., No. 2, 1898). Perhaps the reason for the failure on the part of most writers to grasp the true state of affairs is to be attributed to the misleading method of describing this part of the brain that was introduced by His and has been perpetuated by the Basel Nomenclature Commission. I refer to the subdivision of the region under consideration into anterior and posterior lobules by means of the morphologically unimportant "fissura prima." It is unnecessary to discuss this matter any further, seeing that I have called attention to the common inaccuracies and the places where the true account of the region can be found. In the accom-

¹ This Journal, vol. xxxvii. p. 325.

panying diagram (fig. 4) I have embodied the facts that I wish to emphasise: the position and relations of the pyriform area, especially in the insula; and the situation of the tuberculum olfactorium. The other features of the rhinencephalon represented in fig. 3 have been so often described in this Journal that there is no need to do more than refer to the diagrams themselves.

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A STUDY OF THE NAVICULAR IN THE HUMAN AND ANTHROPOID FOOT. By T. MANNERS-SMITH, M.A., M.B. Cantab., *Demonstrator of Anatomy in the University of Cambridge; Lecturer in Anatomy, Downing College.*

Of the bones of the human foot the navicular is perhaps the most interesting. For this there are various reasons, morphological, mechanical, or both.

In the first place, the bone consists of two components, a body which is a true tarsal element and corresponds to the centrale of the lower vertebrates, and a tuberosity which, as regards its morphology, is doubtful, and not infrequently is separate in its ossification.

Secondly, as an outcome of its cartilaginous state during the first five or six years of life, the navicular, whilst in a plastic state, is subjected to the tension and strain of the structures attached to it, and to the pressure transmitted to it from its neighbours. In consequence, it is moulded into shapes more diverse than those of any other tarsal element.

Lastly, it presents an interesting contrast to its homologue in the upper limb. As a result of its position near the summit of the arch of the foot, of its situation just in front of the transverse tarsal joint, from the fact that it is late (comparatively) in its ossification, and at the same time gives attachment to a powerful muscle, the bone is bold in outline and fairly massive in conformation. Its homologue in the human manus is insignificant in size and contour, and its separate existence is transitory.

The specimens which I was able to examine (about 600 in number) were from the collection of Egyptian bones in the possession of Professor Macalister. It was at his incentive that this paper was written, and I take this opportunity of thanking him for permitting access to his rich store of material, and for many kind suggestions.

I must also thank Dr Duckworth for allowing me to describe the anthropoid navicular bones in his possession.

I am much indebted to Miss Elizabeth Dale for the care she has taken in making the drawings from which the illustrations were prepared.

Nomenclature.

The names which I have chosen for the bone and its surfaces are mostly modifications of those agreed upon by the Basel Convention, together with some of the terms introduced by Professor Pfitzner in his brilliant and laborious paper on the bones of the foot.

I have described the bone as consisting of a chief part or corpus—the os naviculare, which corresponds to the centrale of lower vertebrates—and a tuberosity (tuberositas ossis navicularis) whose nature is unsettled. To the latter of these components an additional element, the tibiale externum, may be added, as Professor Pfitzner has pointed out.

The names in use for some of the surfaces in most English text-books are not in all cases quite accurate. For instance, since the long axis of the bone is oblique rather than horizontal, it is better to call the superior surface dorsal, and subdivide it according to the direction in which its two portions look; and the inferior, plantar, since neither of these surfaces looks exactly in the direction indicated by the names—superior and inferior.

Again, the so-called external surface, which faces the cuboid, is directed as much downwards as outwards—*facies lateralis* or *facies cuboidea* is therefore, perhaps, a better name.

The names which I have adopted are as follows :—

Nomenclature formed on the model of the Basel Convention.	Nomenclature employed by Professor Pfitzner.	Nomenclature in use in England.
Os naviculare.	Naviculare.	Navicular or scaphoid bone.
Processus plantaris.	Cuboides secundarium, also fibulo-plantar corner and lateral plantar process.	Inferior navicular tubercle (Barclay-Smith) or plantar point.
Tuberositas ossis navicularis.	Tuberositas ossis navicularis.	Tuberosity.
	Tibiale externum.	Sesamoid bone in the tendon of the tibialis posticus.

OS NAVICULARE.*Surfaces.*

<i>Facies articularis posterior.</i>	<i>Facies articularis posterior, or facet for caput tali.</i>	Posterior or astragalar surface.
	<i>Facies articularis posterior accessoria. This is that part of the facet for caput tali contributed by Pfitzner's cuboides secundarium.</i>	This would correspond to that portion of the astragalar surface contributed by a large plantar point.

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Nomenclature formed on the model of the Basel Convention.	Nomenclature employed by Professor Pfitzner.	Nomenclature in use in England.
Facies articularis anterior.	Facies articularis anterior medialis, or articulatio cuneo-navicularis I.	The anterior surface for the internal, middle and ex- ternal cuneiform bones.
	Facies articularis anterior media, or articulatio cuneo- navicularis II.	
	Facies articularis anterior lateralis, or articulatio cuneo-navicularis III.	
	Facies anterior intermedia. This is an occasional facet for the dorsal part of cuneiforme I. bipartitum.	An occasional facet for the dorsal part of the internal cuneiform.
Facies dorsalis sup- erior.		Superior surface.
Facies dorsalis medi- alis.		
Facies plantaris.		Inferior surface.
Facies lateralis.	Facies articularis lateralis anterior, or articulatio cubo-navicularis.	Cuboid facet.
	Facies articularis lateralis posterior, or articulatio calcaneo-navicularis.	Occasional calcaneal facet.
		These, together with the non- articular part, constitute the external surface.

TUBEROSITAS OSSIS NAVICULARIS.

Surfaces.

Facies articularis inferior, which is an occasional facet for the tibiale ex- ternum.	Facet for sesamoid bone in tibialis posticus.
Facies articularis tuberosi- tatis.	Occasional facet for astrag- alus.
Facies anterior.	This is continuous with the anterior surface for the cuneiform bones.

Nomenclature formed on
the model of the Basel
Convention.

Nomenclature employed by
Professor Pfitzner.

Nomenclature in use in England.

Facies dorsalis.

This is a continuation of the
dorsal surface of the body.

*Facies plantaris later-
alis.*

This is continuous with the
plantar surface of the body.

*Facies plantaris in-
ferior.*

This joins the last two of the
above surfaces. It forms
the inner and under sur-
face of the tuberosity, i.e.
the "inner end of it."

THE OS NAVICULARE.

Facies Articularis Posterior, or Astragalar Surface. (Figs. 1 to 5.)

The whole of this surface is occupied by the caput tali, and as a rule the caput is confined to this area. In some cases, however, the caput also articulates with the tuberosity.



FIG. 1 —Almost oval.



FIG. 2. —Egg-shaped.

The shape of the facet.—The facet for the caput tali is generally referred to in English text-books as a large oval, concave facet. Pfitzner figures two types of surface, a quadrilateral and an egg-shaped, corresponding to the two types of ground-plan of the navicular which he describes, i.e. a cuboidal and an egg-shaped.

In none of the specimens examined by me is the astragalar facet a perfect oval. It approaches the oval, however, in 33 (fig. 1). It is egg-shaped in 85 (fig. 2). In most cases, however (434), it is pear-shaped (fig. 3). In the last two varieties the narrow end of the egg or pear is directed towards the tuberosity. Sometimes (10) it is almost quadrilateral, occasionally (4) triangular (figs. 4 and 5).

In many of the above specimens, the facet described as pear-shaped

might perhaps have been classed as quadrilateral; it is, however, never absolutely so. Even when the plantar point (fibulo-plantar angle) is prominent and forms, like the apex of the pear (tibio-plantar angle), a distinct angle, there is rarely an angle at the fibulo-dorsal end, and never one at the tibio-dorsal end of the facet (*i.e.* the two ends of the base of the pear). The margo dorsalis posterior forms one curved border, therefore, in

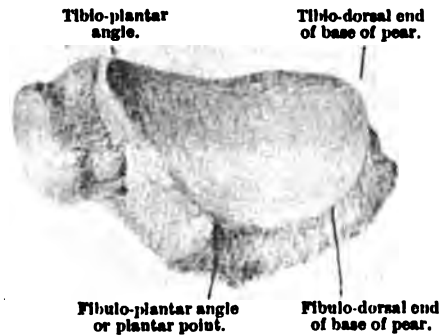


FIG. 3.—Pear-shaped.

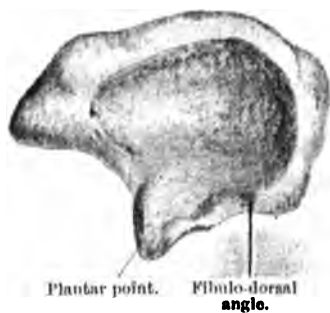


FIG. 4.—Almost quadrilateral.

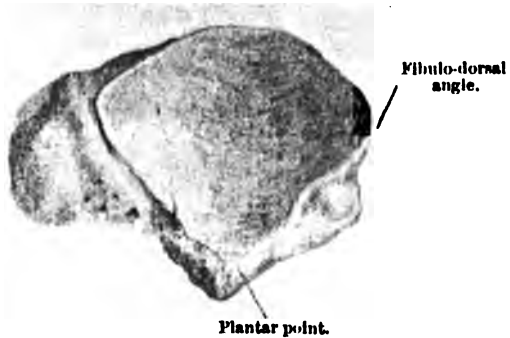


FIG. 5.—Triangular.

all cases. In those rare cases in which there is a fibulo-dorsal angle, either the almost quadrilateral type of facet is present, or, when the margo dorsalis posterior is very short, the whole facet is triangular, with its apex at the plantar point and its base formed by the gently curved margo dorsalis posterior (figs. 4 and 5).

According to Pfitzner, the difference in the ground-form of the navicular, and consequently the difference in the shape of the surface for the caput tali, depends upon the absence or presence of the lateral plantar

process or plantar point; in the first case, we have the egg-shaped, in the second the cuboidal, ground-plan.

He states that the projection of this part of the bone must at once arouse the suspicion that we are dealing with an inconstant, originally independent part of the skeleton, and that this portion of the navicular, in reality, is formed by the assimilation of an inconstant tarsal, namely, what he calls *cuboides secundarium*. If this be so, however, we should expect the process to remain separate in some cases. In none of the specimens which I examined did I find the plantar point existing as a separate ossicle, but in one I found a trace of a suture on the *facies articularis posterior* and *facies lateralis articularis anterior* (cubo-navicular articulation). The facet for the cuboid was subdivided by a groove into two facets; the groove was continuous with the suture on the astragalar surface.

Gruber mentions three similar cases, and Pfitzner conjectures that this arrangement indicates a separation of the joint between the navicular and cuboid from that between *cuboides secundarium* and cuboid.

The large size of this process, however, in the cuboidal type of bone can be explained equally well mechanically as morphologically. It must be remembered, in dealing with this bone, that it is later in its ossification than any of the other tarsal bones, and that the child is walking from about the second to the fifth year with its navicular in a cartilaginous condition. During this period, the inferior calcaneo-navicular ligament is exerting traction on the plantar point, and in this way, supposing the bone ossifies late, and the child is particularly active, the point might easily be drawn out into a prominent process. Its nipple-like appearance in many cases certainly suggests this mode of origin. If, on the other hand, this point is the representative of a separate tarsal element, the tension of the above ligament, by keeping up frequent movement during the early years of childhood, ought certainly, in some cases, to perpetuate the separate existence of this part of the bone, and we should therefore expect to find it occasionally as an independent ossicle, as is sometimes the case with the tuberosity. As stated above, however, and as Pfitzner admits, it has never been found as a separate ossicle in man. For the decisive answer to this question, Pfitzner observes that we must look to embryology. Until an enormous number of fetal tarsi have been examined, the question as to whether this process is a separate element or not cannot be set at rest; but it is significant that the cartilage is a single continuous mass apparently chondrifying from a single centre. Though Gruber's three cases, and my own mentioned above, certainly lend support to Pfitzner's theory that the plantar point is the representative of a

separate tarsal element, at present the evidence is too meagre to warrant us in accepting Pfitzner's view.

The plantar point is well developed in most cases; very small in some of the specimens, and in a few absent. There are two types of plantar point—(a) the spur-like or nipple-like, (b) the rounded. It was spur-like or nipple-like in 318 specimens, and rounded in 134. It appears to be better developed in these ancient bones than in modern specimens.



FIG. 6.—Flattened.



FIG. 7.—Concavity is chiefly in long diameter.



FIG. 8.—Concavity is chiefly in shorter diameter.



FIG. 9.—Concavity is marked in both diameters.

Since the point gives attachment to the inferior calcaneo-navicular ligament, we should expect it to vary directly in size with the development of this ligament. The process, when well developed, may encroach upon the *facies articularis posterior*, and help the inferior calcaneo-navicular ligament to support the head of the talus, extending beneath that structure in a bracket-like manner, and at the same time deepening the articulation.

The Nature and Depth of the Concavity. (Figs. 6 to 9.)

This varies considerably in different specimens. In a few cases it is almost absent, the *facies articularis posterior* being nearly flat. There are two types of concavity:—

(a) That with an increase of the concavity in the long diameter, which depends upon the extent of projection backwards of the upper and outer part of the margo dorsalis posterior (the margin of the broad end of the pear-shaped facet for caput tali), since the tibio-plantar angle (narrow end of the pear) projects considerably backwards in nearly all cases.

(b) That with an increase of the concavity in the shorter diameter, which, in turn, depends upon the projection towards the posterior surface of the plantar point.

When the concavity was especially deep, the increase in most cases (238) was in the longer diameter only, in the shorter diameter only in 55, in both diameters in 82. It is interesting to compare the type of concavity in man with that existing in the Simiidae (fig. 18). In all four genera the depth of the concavity is chiefly in the long diameter, and the plantar point does not extend towards the facies articularis posterior, but is small, and is confined to the facies plantaris. Since movement at the astragalo navicular joint in the Simiidae is especially free, the view is rather suggested that a deeply concave surface for caput tali, in the long diameter, in man, is also correlated with great freedom of movement in a lateral direction at the same joint, and dislocation is thereby prevented during the side-to-side movement. The depth of concavity in the shorter diameter, as in the above 55 cases, since it is dependent chiefly on the projection of the plantar point, and is not found in the Simiidae, is possibly correlated in man with a high and stable tarsal arch.

Anterior Surface. Facies Articularis Anterior. (Figs. 10, 11, and 12.)

Usual description: "Is furnished with a semilunar articular area which is subdivided by two faint ridges into three wedge-shaped facets" (Cunningham). "An oblong-shaped anterior surface, convex, and divided by two vertical ridges into three facets" (Morris). "It presents anteriorly a convex surface divided by two lines converging below into three facets" (Quain).

First, as to the shape of the whole surface. Cunningham's description is the most accurate; the surface is semilunar. The concavity of the half-moon is directed towards the plantar aspect. Secondly, as to the shape of the individual facets. The innermost, for the internal cuneiform, is more or less wedge-shaped, with the apex of the wedge directed towards the tuberosity; the middle facet is also wedge-shaped, with a truncated apex towards the plantar surface; the outermost facet is also a very blunt wedge in many cases, with the narrow end pointing, as a rule, towards the cuboidal facet.

ARTICULATIO CUNEO-NAVICULARIS I.

The Facet for Internal Cuneiform. (Figs. 10 and 12.)

There are two chief types of surface; in the majority (393), the dorsal and plantar borders are on the same vertical level, or the dorsal border is only slightly more projecting than the plantar. In 187 specimens there is a shelving away of this surface towards the plantar aspect of the foot and in the direction of the tuberosity. In addition, the internal cuneiform



FIG. 10. —Gorilla.



FIG. 11.—Chimpanzee.



FIG. 12. —Man.

The figures 10 and 11 show the quadrilateral, concave facet for external cuneiform which is present in all the Simiide. Fig. 12 shows a similar facet which occurs sometimes in man. Figs. 10 and 12 also show the ridge or slight eminence on the facet for the internal cuneiform.

facet has often (170) a very slight vertical or oblique ridge, or eminence, about its middle (figs. 10 and 12). In some cases the ridge or eminence is so strongly developed as to subdivide this surface into two almost equal parts. This ridge probably marks the junction of two components, plantar and dorsal, of the internal cuneiform, which may, in some cases, remain separate. Pfitzner found two surfaces on the navicular at this joint in ten specimens. In those cases where the above eminence is especially well developed, and accompanied by the above-mentioned shelving away of the surface, the internal cuneiform facet is directed very obliquely, its surface

looking somewhat downwards. This will have a tendency to throw the internal cuneiform, and through it the big toe, plantarwards. This is probably correlated with greater freedom of flexion of the hallux, which would be expected in a non-boot-wearing people.

ARTICULATIO CUNEO-NAVICULARIS II.

The Facet for the Middle Cuneiform.

This is also wedge-shaped in most cases, in one triangular; the apex points towards the plantar surface.

The surface is either flattened or slightly concave transversely near the base. In nearly all cases this surface slopes towards the dorsal border, just as the internal cuneiform facet slopes towards the plantar. The direction of this surface would make the posterior aspect of the middle cuneiform look somewhat downwards, and hence the anterior aspect of the same bone look somewhat upwards. This was probably correlated with more freedom of movement of the second toe in an extensor direction, which would be expected in a race not compressing their feet artificially.

In many of those specimens where the above shelving away was pronounced there was a well-marked lipping of the bone at the junction of the dorsal and anterior surfaces, i.e. at the border of the base of the wedge. It is true that in some of these cases the bone was the subject of osteoarthritis, but there were many instances where the bone had been apparently healthy. There is a distinct and direct relationship between this shelving away and the lipping of the bone in this situation.

ARTICULATIO CUNEO-NAVICULARIS III.

The Facet for the External Cuneiform. (Figs. 10, 11, and 12.)

In most cases (239) this facet has the shape of a very blunt wedge with the narrow end of the wedge pointing towards the cuboidal facet; in 59 cases it points towards the plantar surface.

In 189 cases this facet is four-sided, in two pentagonal; with rounded angles near the cuboidal facet in both varieties. This surface is either flattened or concave. It was slightly concave and four-sided in 53 specimens. In a few, markedly concave; see diagram (fig. 12).

When the concavity is well marked and this facet is four-sided, we have the anthropoid type of articular surface in this situation. It is especially well marked in the gorilla, but is present in all the Simiidæ (figs. 10 and 11).

Direction of this surface.—It shelves away considerably in nearly all cases towards the lateral and dorsal surfaces, so that it looks rather more outwards and upwards than in modern bones. The outward direction would have the effect of throwing the long axis of the external cuneiform, and through this the middle metatarsal bone, outwards. The upward direction would have the effect of throwing the posterior surface of the external cuneiform downwards, the anterior surface, and with it the third metatarsal bone, upwards. This is probably correlated with greater freedom of extension and abduction of the middle toe.

Facies Dorsalis Superior.

This is that part of the so-called superior or dorsal surface of English text-books which looks upwards and outwards.

The most interesting point in connection with this surface is the presence, in some cases, of a groove which runs obliquely forwards and inwards. It was present in 65 specimens. The depth of the groove is variable; it must not be confused with another groove which is occasionally present and runs in the opposite direction—forwards and outwards. The first of the two grooves is for the attachment of ligaments, namely, the lateral (external) astragalo-navicular and the dorsal cubo-navicular ligaments. The second is probably for the tarsal branch of dorsalis pedis artery. This artery, however, is so variable in its origin and course, that I was not able to satisfy myself that the occasional groove was a vascular one. A third groove may be present, at the junction of the facies dorsalis superior and the facies lateralis, and close to the articulation cubo-navicularis when that articulation is present. This is for the attachment of the external calcaneo-navicular ligament.

Facies Dorsalis Medialis.

This is that part of the so-called superior or dorsal surface of English text-books which looks upwards and inwards.

A ridge is present in many of the specimens (363) on this surface, about one-sixth of an inch from the margo dorsalis anterior, and parallel to it; between the ridge and the margin is a narrow groove in most of the above (363) specimens. This ridge and groove are for the attachment of the ligaments connecting this bone with the cuneiform bones.

In some cases, the above-mentioned ridge is broken by a slight depression opposite the middle cuneiform. This depression is in the position of the dorsalis pedis artery. I could not be certain, however, from

an examination of recent specimens, that the dorsalis pedis artery indented the bone here.

In many cases (238), there is a second ridge one-sixth of an inch from the margo dorsalis posterior. It bounds anteriorly a slight groove situated between the ridge and the margin. This ridge and groove are for the ligaments connecting the navicular with the talus.

In some cases there is a third shallow groove or depression placed between the two ridges, and midway between the margo dorsalis anterior and posterior.

Facies Lateralis.

This extends from the facies dorsalis superior to the facies plantaris. It is described in English text-books as the external surface, but it looks almost as much downwards as outwards. It is rough in most of its extent. Its chief points of interest are: (*a*) the frequent presence of a facet for the cuboid; (*b*) an occasional facet for the os calcis; (*c*) a small tubercle, the plantar point, which has already been described.

Articulatio Cubo-navicularis. (Figs. 15 to 18.)

The cuboid facet is situated at the junction of the facies articularis anterior and facies lateralis. It is present in 332 specimens, or about 70 per cent. of those examined with reference to this surface.

Pfützner found a distinct joint here in 50·4 per cent., Gruber in 45·5 per cent. According to him, it is more frequent in the female than in the male. Of the 332 specimens in which I found it, 163 out of 274 examined belonged to the right, and 168 out of 260 examined to the left side. In my specimens, therefore, it appeared to be rather more frequent on the left side. Its shape is somewhat variable; in most cases it is four-sided, with the posterior angles rounded off (fig. 15). In some of these it is almost square (54), in others oblong (4). In some cases (142) it is wedge-shaped, with the base of the wedge directed anteriorly (fig. 16). In a few it was semilunar (4) or rhomboidal (4). In all cases the border which separates it from the facet for the external cuneiform is sharp and well marked. The facet varies in size from a threepenny piece to a large pin's head. There is nearly always a rough interval, which is generally depressed or grooved, between this facet and that for the caput tali. In some instances the cuboid facet nearly approaches the facet for the caput tali, and occasionally quite reaches it, extending from the articulatio cuneo-navicularis III. to the facies articularis posterior. Not infrequently the facet extends on to the plantar point (fig. 17). Pfützner would regard these cases as due to extension of the cubo-navicular joint to a cuboides secundarium.

Some additional evidence against his view is gathered from the fact that the cubo-navicular joint extends on to the plantar point in the



FIG. 13.



FIG. 14.



FIG. 15.



FIG. 16.

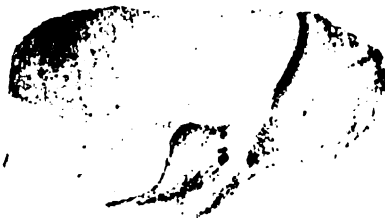


FIG. 17.—Man.



Plantar point.

FIG. 18.—Chimpanzee.

FIGS. 13 and 14 show occasional facet for os calcis. FIGS. 15 and 16 show quadrilateral and wedge-shaped facets for cuboid. FIGS. 17 and 18, extension of the cuboidal facet on to the plantar point in man and the chimpanzee. FIG. 18 also shows that the concavity for caput tali is almost entirely in the long diameter in the chimpanzee. This is so in all the Simiidae.

Simiidae, in which this process is generally insignificant, does not project towards the astragalar surface, and does not give a cuboidal outline to the bone (fig. 18).

Articulatio Calcaneo-navicularis. (Figs. 13 and 14.)

This occasional facet for the os calcis is present in 13 specimens, 8 right and 5 left. The facet is close to the surface for caput tali, between the cuboidal facet and the plantar point. Its shape varies slightly: in two cases it was rhomboidal, in one triangular, in one oblong and in one wedge-shaped; in three cases there was a fairly sharp ridge separating it from the cuboidal facet. Pfitzner found this articulation in 8 specimens. The presence of this articulation is due, according to Pfitzner, to the existence of a rudimentary calcaneus secundarius which has fused with the os calcis.

Facies Plantaris.

By this is meant that surface between the plantar point and the tuberositas ossis navicularis. It is directed downwards. It presents many foramina for nutrient vessels. In most cases it is marked by an oblique groove, situated at the junction of the tuberosity with the body of the bone. This groove commences posteriorly between the tuberosity and the facet for the caput tali, and runs obliquely forwards and outwards along the plantar surface, to terminate at the margo-plantaris anterior. The groove varies in depth in different specimens; in some cases it is almost as deep as the groove on the cuboid for the peroneus longus tendon. The groove occupies the greater part of the inferior surface. It lodges that portion of the tibialis posticus tendon which passes to the metatarsal bones

Tuberositas Ossis Navicularis.

This may be considered, from a descriptive point of view, under size, prominence, and shape, and from a morphological, embracing the embryology of the tuberosity, its components and their nature.

Description.—In the following account I have included as tuberosity that portion of the whole navicular which projects mesially and plantarwards, beyond a line drawn round the bone from the tibio-plantar angle (apex of pear-shaped facet for caput tali) to the apex of the facet for the internal cuneiform.

Size.—This may be discussed under (a) the absolute size of the tuberosity; (b) the size of the tuberosity compared with the size of the corpus.

(a) The tuberosity in some cases is extremely large, in others almost absent. Its size depends partly upon the number of morphological elements which it contains, and partly on the traction exerted on it during life by the tibialis posticus muscle.

(b) In some few cases, a large bone had a large tuberosity; there is no direct relationship, however, in most cases, between the size of the corpus and tuberosity, for whilst some of the smaller bones have a well-developed process, forming, occasionally, one-third of the whole bone, in some of the larger the tuberosity is insignificant. This would be expected from the morphology of the tuberosity.



FIG. 19.



FIG. 20.



FIG. 21.

FIG. 19 shows the elongated type of tuberosity in man. Figs. 20 and 21, the tuberosities as they exist in the gorilla and chimpanzee; figs. 20 and 21 also show that the concavity of the surface for caput tali is in the long diameter in these animals.

Shape.—With reference to shape, there are two chief types of tuberosity.

(1) In most cases (345) the tuberosity is a somewhat four-sided prism with the angles rounded off. Of the 345, 173 belonged to the right side, 172 to the left. In these cases the tuberosity possesses the following surfaces:—

A facies anterior, which is continuous with the facies articularis anterior of the body. It is frequently marked by a slight groove for a ligament between the tuberosity and the internal cuneiform.

A *facies dorsalis*, which is continuous with the *facies dorsalis medialis* of the body. It has often a depressed cribriform area for nutrient vessels.

A *facies plantaris lateralis*, which is continuous with the *facies plantaris* of the body.

A *facies plantaris inferior*, joining the last two surfaces. In some cases this surface is very small or non-existent, the *facies dorsalis* and *plantaris lateralis* meeting here in a ridge or nipple-like process.

(2) The other type of process is the elongated. This occurred in 109 cases out of 454 examined with reference to the tuberosity, or about 25 per cent. It occurs with rather greater frequency on the right side than on the left, thus:—

In 239 right it occurred in 66 cases, or about 28 per cent.

„ 215 left „ „ 43 „ „ 20 „

In the elongated type of tuberosity the *facies anterior* is non-existent as a distinct surface, and shelves away into the *facies plantaris inferior*. In addition, the apex of the bone is produced proximally, and generally terminates in this direction in a nipple-like manner. It is this variety which may carry the abnormal surface, *facies articularis tuberositatis*, for the *caput tali*.

The manner of production of these two types of tuberosity will be mentioned later.

The apex of the tuberosity may occupy three situations:—

(a) It may be situated at a small tubercle close to and dorsalwards of the tibio-plantar angle (apex of pear-shaped astragalar facet). This may be called the *apophysial apex*.

(b) It may be situated a line or two on the distal side of and plantarwards of the above tubercle. This may be called the *epiphysial apex*.

(c) It may be produced proximally, so as to occupy a position $\frac{1}{4}$ to $\frac{1}{2}$ of an inch posterior to the above tubercle. This may be called the *sesamoid apex*.

Ossification.

Anatomists are agreed that the navicular is ossified as a rule from a centre which is situated in the body and appears between the third and the sixth year—to be more exact, according to most British anatomists and to Béclard, between the fourth and fifth years, and according to Rambaud and Renault, at the age of from four and a half to five and a half years.

The occurrence of the process of the navicular tuberosity as an exceptional epiphysis, or later as an articulating ossicle, cannot therefore, as

Gruber states, be explained from the usual course of development. It will be discussed under the next heading.

Morphology.

The portion of bone included in the above description as tuberosity will be found to consist of a variable number of elements of different morphological value. The evidence derived from those abnormal cases in which a separate ossicle is found in this situation would suggest that the whole tuberosity is made up of one, two, or in some cases three components:—

(a) A portion near the corpus which is merely an apophysis of that body. From this the whole of the *facies anterior* and *facies dorsalis* and *facies articularis* are formed, together with a little tubercle at the upper part of the latter surface and close to the tibio-plantar angle (apex of the pear-shaped facet for *caput tali*).

This apophysial element is a distinctly wedge-shaped portion of bone, with its base at the *facies anterior* and its apex (apophysial apex) at the above-mentioned tubercle near the tibio-plantar angle. Its surface for articulation (*facies articularis*) or coalescence with the epiphysial part of the tuberosity is slightly concave, and has an oval, quadrilateral, or circular outline, and is rough for the junction of the epiphysial portion of the tuberosity (fig. 24). It has generally a raised margin. If the epiphysial portion is absent, the so-called *facies articularis* forms the free *facies plantaris lateralis*.

(b) The epiphysial portion, corresponding apparently to the *naviculare secundarium* of Gruber. The part formed from the epiphysis is either prismatic or oval in shape, the exact shape depending on the presence or absence of a third element of the tuberosity. In the prismatic type it possesses four surfaces—a *facies articularis* which fuses or articulates with the *facies articularis* of the apophysial portion; two surfaces which form most of the *facies plantaris lateralis* and *facies plantaris inferior* of the tuberosity; and lastly, the base of the prism, which is directed backwards in the natural position of the bone. This is more or less concave, and receives the base of the third element of the tuberosity with which it fuses. In the oval type the epiphysial portion is a mere lamina of bone.

(c) The last and most variable element of the tuberosity is the so-called sesamoid bone in the tendon of the *tibialis posticus*, which may fuse with the tuberosity. When it is present it produces the tuberosity proximally, and is somewhat pea-like in shape, resembling closely the human pisiform bone (fig. 26). It is the presence of this element which gives rise to the elongated type of tuberosity described earlier; with its absence we have the prismatic

type. When this element is present there is not infrequently an extension



FIG. 22.



FIG. 23.



FIG. 24.



FIG. 25.

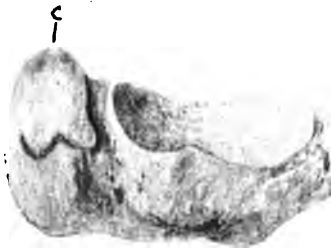


FIG. 26.

Figs. 22 and 23 show separate ossicles, and there is a tendency to subdivision in fig. 23. In fig. 24, the whole ossicle has disappeared; the surface with raised margins is the facies articularis of the apophysial portion, for articulation or coalescence with the epiphysial portion. In fig. 25 the sesamoid element only has disappeared; the epiphysial element remains, and presents a concave surface for coalescence or articulation with the sesamoid portion. In fig. 26 the ossicle has fused; its line of junction can, however, be seen. A, apophysial apex; B, epiphysial apex; C, sesamoid apex.

of the surface for caput tali on to the tuberosity (facies articularis tuberositatis).

The single bone which Pfitzner describes as *tibiale externum* corresponds in shape and position to the parts described above under (*b*) and (*c*). It is true that we only get a single separate ossicle in this position. In one of my specimens (fig. 23), however, the ossicle was imperfectly bipartite, and Pfitzner mentions five cases in which it was in the same condition. This would suggest the view that the single ossicle may consist of both of the above-mentioned elements (*b*) and (*c*) fused. It may be conjectured from the shape of the articular surfaces, or from the lines of coalescence, which element is missing, as shown in the accompanying diagrams (figs. 24 and 25).

Gruber mentions a case where there was an element apparently corresponding to my epiphysial portion, which he calls *naviculare secundarium*. It was *contracted* in the foot of one side and *ankylosed* on the other. He also depicts a navicular with a large migrated sesamoid, and which he cautions us against confusing with the above-mentioned *naviculare secundarium*.

Although, as Pfitzner maintained, the sesamoid bone in the *tibialis posticus* (*tibiale externum*, Pfitzner) may fuse and form part of the tuberosity, it probably only forms the proximal portion of the tuberosity, and the occasional bipartite condition of the ossicle found here, together with the shape of the surfaces of articulation or coalescence, would suggest that there is another element between this sesamoid element and the apophysial part of the tuberosity, namely, that which I have described as the epiphysial portion. Bardeleben has shown that there is a separate cartilage at the tuberosity up to the second month of foetal life. Pfitzner, however, apparently would claim this cartilage as the same element as his *tibiale externum*. The matter can only be settled by the examination of a large number of young tarsal bones varying in age, preferably from the fifth to the twenty-fifth year.

THE OS NAVICULARE IN ANTHROPOID APES. (Figs. 10, 11, 18, 20, and 21.)

ANTHROPOIDEA. SIMIIDÆ.

GORILLA.

Facies Posterior.

The outline of the surface more nearly approaches an oval than in any of the other Simiidae, but is really shoe-shaped in outline, with the heel of the shoe directed downwards and inwards.

Depth of concavity.—It is deeply concave in the long diameter, the

two ends projecting backwards about equally. There is no great depth of concavity in the shorter diameter. The plantar point is present, but does not encroach upon this surface, being separated from it by about one-fourth of an inch.

Facies Anterior.

The general outline of this surface is semilunar.

Articulatio cuneo-navicularis I.—This is wedge-shaped, and very like that variety in man which shelves away towards the plantar surface and tuberosity.

Articulatio cuneo-navicularis II.—This is also wedge-shaped, and shelves away towards the dorsum in a similar way to that existing in the human subject (ancient bones).

Articulatio cuneo-navicularis III.—Quadrilateral in shape and deeply concave, its concavity suggesting the articulation between the os magnum and the scaphoid.

Facies Lateralis.

Articulatio cubo-navicularis.—This facet forms an oblong figure extending from the facies dorsalis superior to the plantar point.

Facies Dorsalis Superior.

This is wedge-like in outline. It has a groove near and parallel to the margo dorsalis anterior.

Facies Dorsalis Medialis.

This is marked about the middle by a well-developed ridge which commences in a tubercle superiorly. The ridge separates two grooves which are situated respectively between it and the margo dorsalis anterior and the margo dorsalis posterior.

Facies Plantaris.

The groove is present, separating the tuberositas ossis navicularis from the os naviculare, as in the human subject.

Tuberositas Ossis Navicularis.

This is of the elongated type.

ANTHROPOPITHECUS TROGLODYTES.

Facies Posterior.

This surface is pear-shaped, and deeply concave in the long diameter. The plantar point is small, and does not project towards or encroach upon this surface, but helps to support the cuboidal facet.

Facies Anterior.

Articulatio cuneo-navicularis I.—This is wedge-shaped, and shelves away considerably towards the plantar surface.

Articulatio cuneo-navicularis II.—This facet shelves away considerably towards the dorsal surface—much more so than in the human subject.

Articulatio cuneo-navicularis III.—This is a quadrilateral facet, and is deeply concave.

Facies Dorsalis Superior.

Very small in extent: not grooved.

Facies Dorsalis Medialis.

There is a well-marked ridge on this surface, which corresponds to that ridge in the human subject which is near the margo dorsalis anterior; there is a depression behind it close to the facies posterior.

Facies Plantaris.

There is a very narrow oblique groove between the body and tuberosity.

Facies Lateralis.

Articulatio cubo-navicularis.—The articulation occupies the whole of the surface and encroaches upon the plantar point.

Tuberositas Ossis Navicularis.

This is four-sided; the apex is somewhat blunt.

SIMIA SATYRUS.

Facies Posterior.

In shape it is almost oval. It is deeply concave in the long diameter. The plantar point does not encroach upon this surface.

Facies Anterior.

Articulatio cuneo-navicularis I.—This facet is wedge-shaped, and does not shelve away towards the plantar or dorsal surfaces. It shelves away towards the tuberosity.

Articulatio cuneo-navicularis II.—This part slopes away considerably towards the dorsal surface.

Articulatio cuneo-navicularis III.—This is quadrilateral in shape and is deeply concave, as in the gorilla and chimpanzee. It looks forwards and outwards.

Facies Dorsalis Superior.

Oblong in shape: possesses a slight groove near the margo dorsalis anterior.

Facies Dorsalis Medialis.

Possesses a slight ridge separating two grooves, as in the gorilla.

Facies Plantaris.

There is no groove on this surface between the body of the bone and the tuberosity, as in the gorilla.

Facies Lateralis.

Articulatio cubo-navicularis.—This facet is somewhat wedge-shaped, with the broad end of the wedge supported by the plantar point.

Tuberositas Ossis Navicularis.

In this family the tuberosity is either small or non-existent.

*HYLOBATES.**Facies Posterior.*

Oval in shape and deeply concave in the long diameter, in consequence of the projection of the tuberosity backwards and upwards. The tuberosity therefore helps to support the head of the astragalus.

Facies Anterior.

Articulatio cuneo-navicularis I and II. are flatter than in the other anthropoid apes examined.

Articulatio cuneo-navicularis III. is slightly concave and somewhat wedge-shaped.

Facies Dorsalis Superior.

Oblong and smooth.

Facies Dorsalis Medialis.

There is a slight concavity crossing the bone, from the margo dorsalis anterior to the margo dorsalis posterior.

Facies Plantaris.

There is no oblique groove on this surface.

Tuberositas Ossis Navicularis.

The tuberosity, though small, is prolonged proximally, and helps to support the head of the astragalus.

Summary of the most Interesting Particulars observed in the Specimens examined.

(1) The variability in shape and the two types of concavity of the facies articularis posterior.

(2) The encroachment of the plantar point on this surface, and its projection upwards and backwards beneath the caput tali.

(3) The presence of a faint suture between the astragalar surface of plantar point and the rest of the navicular surface for caput tali, in one specimen.

(4) The plantar point appears to be better developed in these bones than in modern specimens. This is probably correlated with a higher tarsal arch.

(5) Increase of concavity, in the long diameter, of the facies articularis posterior, is probably correlated with freedom of movement at this joint.

(6) The two types of surfaces at the articulatio cuneo-navicularis I, i.e. the flattened and the ridged.

(7) The shelving away of the surface for articulatio cuneo-navicularis II. towards the margo dorsalis anterior.

(8) The great shelving away of the surface for articulatio cuneo-navicularis III. towards the facies lateralis.

(9) The frequent presence of a quadrilateral and concave surface at articulatio cuneo-navicularis III., as in the Simiidae.

(10) The grooves on the facies dorsalis superior.

(11) The two ridges and grooves for ligaments on the facies dorsalis medialis.

(12) The frequent presence (70 per cent.) of the articulatio cubo-navicularis.

(13) The extension of articulatio cubo-navicularis on to plantar point in some cases.

(14) In one of the above cases there was a slight gap between the part of the cuboidal facet contributed by the plantar point and that contributed by the rest of the navicular.

(15) The occasional presence of an articulatio calcaneo-navicularis.

(16) The existence of the tuberosity as a separate ossicle in some cases, and the shape of the articulating or coalescing surfaces.

(17) Evidence suggesting that the tuberosity consists of three elements in many cases—an apophysial, an epiphysial, and a sesamoid.

(18) The two types of tuberosity, the prismatic and the elongated, these being dependent upon the morphological elements which the tuberosity contains.

(19) The occasional presence of a facet for caput tali on the posterior and outer surface of the proximal part of the tuberosity (facies articularis tuberositatis).

(20) The fact that the concavity of the facet for caput tali in anthro-poid apes is chiefly in the long diameter.

(21) The quadrilateral concave surface of articulatio cuneo-navicularis III. in the same animals.

(22) The small size of the plantar point in all the Simiidae, its non-encroachment on the astragalar surface, and the fact that it often supports the articulatio cubo-navicularis.

From the above summary it is evident that the navicular bone offers many interesting points for our notice. Some of these characteristics are mainly of morphological import, such as the number of elements included in the tuberosity, the occasional existence here of a separate ossicle, the nature of this ossicle and its relationship to Pfitzner's tibiale externum.

Others are suggestive of a mechanical significance—for instance, the shelving of the cuneiform surfaces, which is apparently more marked in these Egyptian bones than in modern specimens. This was probably correlated with greater freedom of movement of the digits, which in turn was no doubt dependent upon the fact that the feet of these ancient people were not compressed artificially.

The plantar point is probably dependent on traction or a traction outgrowth, unless we adopt Pfitzner's view and regard it as the representative of a separate tarsal element. It has also a purely mechanical function, supporting the arch of the foot in a bracket-like manner.

Lastly, certain features are of both morphological and mechanical

interest, such as the shape of the articulation for the caput tali, and the nature, direction, and depth of this concavity in man and the Simiidae: all of these characteristics being correlated with the extent and variety of movement at the transverse tarsal joint, in man and the anthropoid apes.

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VARYING POSITIONS OF THE CARPAL BONES IN THE DIFFERENT MOVEMENTS AT THE WRIST. By HENRY M. JOHNSTON, M.B., *Chief Demonstrator of Anatomy, Trinity College, Dublin.*

PART II.

(a) PALMAR AND DORSAL FLEXION.

(b) RADIAL AND ULNAR FLEXION COMBINED WITH PALMAR AND DORSAL FLEXION.

IN Part I. of this communication (*Journal of Anat. and Phys.*, vol. xli. p. 109) there will be found an account of the method employed in this investigation. The relations of the carpal bones to one another were described in four positions of the wrist-joint, viz., extension, slight ulnar flexion, complete ulnar, and complete radial flexion.

In this, the second part of the communication, specimens will be dealt with which illustrate palmar and dorsal flexion, and combinations of these movements with radial and ulnar flexion. The varying positions of the carpal bones in palmar and dorsal flexion have not been very fully investigated. Other authors have directed their attention mainly to the movements of radial and ulnar flexion. This is due to the difficulty which exists in obtaining satisfactory X-ray pictures of the bones, when the hand and forearm do not lie in one plane. H. Virchow¹ has given an account of the changes in position assumed by the scaphoid bone in palmar and dorsal flexion of the hand, estimating these changes by driving pins into the various bones at right angles to their surface planes. His specimens were prepared by the frozen method. With the exception of Virchow's figures but few illustrations exist of the wrist-joint in varying degrees of antero-posterior flexion. When looking at the drawings illustrating this paper, it is necessary in each case to bear in mind the angle of deviation of the hand from the straight position, both in an antero-posterior and in a lateral direction. This is the more necessary as several of the drawings show the preparations viewed somewhat from the side.

¹ "Die Weiterdrehung des Naviculare carpi bei Dorsalflexion," *Verh. Anat. Ges.* 16, Vers 7.

DESCRIPTION OF PREPARATIONS.

Left Wrist in Full Palmar Flexion.

Seen from the front (fig. 9).—A certain amount of ulnar flexion will be noticed accompanying the palmar flexion, for it is impossible to prevent this when any great degree of palmar flexion takes place. Very little articular cartilage is visible, but a good deal of the cartilage on the inferior surface of the radius is free, and overhangs the scaphoid and lunar in front (not shown in fig. 9). The facet on the lower end of the radius for the scaphoid bone is much more uncovered than that for the lunar (see diagram), the greatest amount being exposed on the radial side of the ridge which divides the inferior surface of the radius into its two facets.

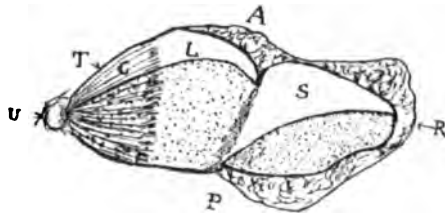


Diagram to show the relationship of the lower aspect of the radius and triangular fibro-cartilage to the first row of carpal bones in full palmar flexion. The areas not dotted are free.

8, L, correspond to portions of facets uncovered by scaphoid and lunar bones respectively; C, indicates the area on the lower aspect of the triangular cartilage T, which is free; A, anterior edge of the radius; P, posterior edge of the radius; U, styloid process of the ulna.

The facet for the lunar bone is most exposed at the ulnar side. A considerable part of the inferior surface of the triangular fibro-cartilage is free in front, owing to the backward movement of the lunar and pyramidal bones. The lunar will be found to touch the antero-posterior ridge on the lower end of the radius, just as it does in ulnar flexion; and the portion of the facet for the scaphoid on the radius which is not free, is covered by the superior scapho-lunar ligament and by part of the superior articular surface of the scaphoid bone. All the first row of carpal bones are markedly volar flexed, and this condition is most noticeable in the case of the scaphoid bone *d* (see fig. 9). Its tubercle has travelled forwards and upwards to such an extent that it lies in front of the anterior edge of the lower extremity of the radius; consequently, the part of the scaphoid which bears the semilunar facet for the lunar bone has been thrust far back, and very little of the scaphoid is seen from the front. The ligamentous con-

nection between the scaphoid and lunar bones causes the latter to become volar flexed; but, owing to the laxity of these ligaments, the lunar bone does not move so far backwards as the scaphoid, and consequently, the semilunar facets on these bones having moved on one another, a strip of the articular cartilage on the lunar bone is exposed in front. This move-



FIG. 9.—Left wrist-joint in palmar flexion,
seen from the front

Amount of palmar flexion = 40°.
Amount of ulnar flexion = 15°.



FIG. 10.—Left wrist-joint in palmar flexion,
seen from behind.

ment between these two bones of the first row was not found to take place to any appreciable extent in radial or ulnar flexion.

At the mid-carpal joint we notice the trapezium and trapezoid bones accurately meeting the scaphoid, and no articular cartilage is exposed; but in the case of the articulation of the scaphoid bone with the os magnum, a small portion of the concave articular facet of the former is exposed in front of the upper part of the head of the latter bone (not seen in drawing). The head of the os magnum shows no articular cartilage in front, but the

concave facet on the inferior surface of the lunar bone is free in front to the extent of 2 mm., measured from above downwards. Examining next the articulation between the unciform and lunar bones, we find that their articular facets just touch, and no articular cartilage of either facet is visible. Finally, between the unciform and pyramidal bones we notice imperfect coaptation, a strip of cartilage on the inferior surface of the pyramidal being free in front. If the joint between the os magnum and unciform be examined, we see that the os magnum, having volar flexed more than the unciform, a gliding movement has occurred between these two bones. At the upper part of the articulation between them, a strip of cartilage, 1 mm. in breadth, belonging to the articular facet on the unciform, is exposed (not seen in drawing). As regards the pisiform bone, in this position of the hand it is separated from the pyramidal at least 5 mm., being lifted off the latter by the action of the flexor carpi ulnaris muscle. This is permitted, as the capsular ligament between these bones is very loose.

Seen from behind (fig. 10).—By far the most striking feature is the large amount of articular cartilage exposed. The scaphoid bone shows the greater part of its superior surface, the ulnar extremity of this surface being altogether out of contact with the inferior surface of the radius. When the wrist-joint in the living subject is examined in palmar flexion, the superior surface of the scaphoid bone, covered by the soft tissues, forms a marked projection which can readily be seen and felt on the back of the carpus to the ulnar side of the line of the tendon of the extensor longus pollicis muscle. The lunar bone also shows on its superior surface a considerable amount of cartilage, which is out of contact with the radius. Between the constituent bones of the first row we have, as on the palmar aspect, evidence of the movement between the scaphoid and lunar mentioned above; and the scaphoid, besides gliding backwards on the lunar bone has separated from it posteriorly as much as the connecting ligaments will permit. A greater amount of articular cartilage is exposed at the mid-carpal than at the radio-carpal joint. Between the scaphoid, trapezium, and trapezoid bones, the transverse furrow described in Part I. lies wide and deep, and its boundaries in the deepest parts are formed by the opposing articular facets of those bones which fail to meet posteriorly. The part of this furrow corresponding to the interval between the trapezium and scaphoid bones is rather shallow. The furrow is closed at its ulnar extremity by the head of the os magnum, and here its upper and lower boundaries are formed by the opposing facets for the trapezoid and scaphoid bones. The ulnar end of the furrow corresponds to its widest and deepest part (10 mm.). The scaphoid bone, besides leaving bare an

extensive area on the side of the head of the os magnum, also leaves an area 1.5 mm. in extent exposed on the summit of the head of the os magnum at the radial side of the radial ridge on the head. More anteriorly, however, the scaphoid bone meets the radial ridge exactly. Turning now to the joint between the lunar bone and the os magnum, we find that these bones are separated posteriorly by a slight gap, but at the bottom of this they are in close contact with one another. Fully 9 mm. width of cartilage on the head of the os magnum is exposed. Perhaps the most remarkable feature remains to be noticed. The slight furrow between the lunar bone and the os magnum is continuous with a very broad and deep cleft between the unciform below and the lunar and pyramidal bones above. This space at its widest part, *i.e.* between the unciform and lunar bones, is 8 mm. across, and before a depth of 10 mm. is reached, the bones do not come in contact. The lower boundary runs from behind forwards and upwards, while the upper side of the cleft extends more directly antero-posteriorly. Between the pyramidal and unciform the interval is not so deep, and it is closed on the ulnar side by the meeting of these two bones. This interval between the two rows of carpal bones at the ulnar side is quite evident in the living subject when the dorsal surface of a palmar flexed wrist is palpated. If, however, palmar flexion is complete, the ligaments (*d*) are tightly stretched over the space and render the gap less easily appreciated. Between the unciform and the os magnum there is evidence of the gliding movement that has occurred at this situation (p. 283).

SUMMARY OF IMPORTANT CHANGES IN PALMAR FLEXION.

1. Complete palmar flexion is always associated with some degree of ulnar flexion.
2. Owing to the extensive palmar flexion of the first row of bones, especially of the scaphoid, a considerable area of the inferior articular surface of the radius is exposed in front.
3. Evidence of movement between the semilunar and scaphoid and between the unciform and os magnum.
4. The large amount of the articular facets on the bones exposed posteriorly is characteristic of palmar flexion, and the intervals left between the two rows of carpals at the radial and ulnar side of the wrist are also noteworthy.

Notes on some of the above Changes.

- 1, 2. The action of the flexor muscles causes the trapezium and trapezoid to come forward, and as a result of this movement the lower end of the

scaphoid is pushed upwards and inwards. At the same time the upper end of the scaphoid bone moves backwards and outwards, and the lunar is drawn as far to the radial side as the antero-posterior ridge on the inferior articular surface of the radius will permit. Hence as much ulnar flexion takes place at the radio-carpal joint as is possible. The flexor carpi ulnaris not only causes the unciform to flex, but also to glide upwards and backwards on the pyramidal bone (thus assisting in the volar flexion of the latter), till its movement is brought to an end, when it comes into contact with the lunar. This movement of ulnar flexion at the mid-carpal joint tends to cause the tubercle of the scaphoid to move downwards (see Part I., p. 116). The scaphoid is thus subject to two opposing forces, and the movement of palmar flexion is brought to an end when these two forces are of equal amount.

Left Wrist in Dorsal Flexion.

In this specimen about 5–10 degrees of ulnar flexion is present along with the dorsal flexion, but owing to the fact that the specimens were drawn as viewed, somewhat from the side, a much greater amount of ulnar flexion is suggested. In life the wrist can be dorsally flexed to its full extent, and still the third metacarpal can be maintained in line with the central axis of the forearm; but when the hand is *placed* in a dorsiflexed position, it tends to deviate slightly to the ulnar side.

Seen from the front (fig. 11).—Marked dorsiflexion of the bones of both rows is seen. The change in position of the scaphoid bone is most marked (compare figs. 9 and 11). The tubercle has been drawn downwards to so great a degree that a very large area (10 mm. across) of the articular facet for the radius is exposed. The lunar also shows an extensive area of articular cartilage, broadest towards the radial side. This bone, as well as the scaphoid, is slightly separated from the lower end of the radius in front. The lunar completely occupies the quadrilateral articular facet on the inferior surface of the radius, and the radial end of its superior surface touches the antero-posterior ridge on the radius. The first row of bones therefore, as regards their relationship to the radius, are in a position of ulnar flexion. The scaphoid and the lunar bones are separated from one another and the ligaments uniting them are stretched. The semilunar facets on these bones correspond. At the mid-carpal joint passing from the radial to the ulnar side we see a portion of the superior facets of the trapezium and trapezoid bones exposed. The head of the os magnum has come forwards so far that it has cartilage exposed on all sides. Especially noteworthy is a small area in front of the unciform (compare p. 283), the

presence of which proves conclusively that in the passage from palmar to dorsal flexion a distinct gliding movement of a rotatory nature takes place between these two bones. Turning now to the articulation between the unciform and lunar bones, we find that they fail to meet, and a gap 1.5 mm. across is left between them. Lastly, the unciform is very imperfectly in contact with the pyramidal; its hook has moved far downwards and back-



FIG. 11.—Left wrist-joint in dorsal flexion,
seen from the front.

Amount of dorsal flexion = 45°.
Amount of ulnar flexion = 5°-10°.



FIG. 12.—Left wrist-joint in dorsal flexion,
seen from behind.

wards, and the articular surface for the pyramidal bone is completely out of gear at the ulnar margin of the wrist.

Seen from behind (fig. 12), we notice how closely the lower end of the radius approaches the metacarpal bones, and the deep and wide furrow which now extends across the whole carpus posteriorly. In the floor of this furrow, at the radial and ulnar sides of the wrist, we notice two secondary furrows, separated from one another by the os magnum. These grooves are far less conspicuous than in the palmar-flexed condition of the wrist-joint. At the radio-carpal joint the scaphoid only exhibits a narrow

strip of cartilage below the radius, and the non-articular posterior surface alone of the lunar bone can be seen. At the mid-carpal joint, the groove at the radial border of the wrist is almost closed, but the scaphoid shows about 3.5 mm. of articular cartilage at the joint between it and the trapezium and trapezoid bones. The head of the os magnum is completely covered by the lunar and scaphoid bones, together with (in the recent state) the superior scapho-lunar ligament. The unciform fails to meet the lunar bone, and a cleft is also seen between the unciform and pyramidal; but the opposing articular facets of these latter two bones are adapted much more accurately to one another than in palmar flexion of the wrist-joint (compare figs. 10 and 12).

SUMMARY OF IMPORTANT CHANGES IN DORSAL FLEXION.

1. With complete dorsal flexion there is about 5°–10° of ulnar flexion at the radio-carpal joint. This, by muscular effort, is capable of being neutralised by radial flexion at the radio-carpal joint, so that it is possible to keep the third metacarpal bone in line with the central axis of the forearm when dorsiflexion has reached its full limit.
2. The change in the direction of the long axis of the scaphoid bone is most marked. It is now almost in a line with the long axis of the radius.
3. The second row of bones is dorsiflexed to even a greater degree than the first row. This is shown by the partial exposure of the superior facets of the trapezium and trapezoid bones in front of the lower end of the scaphoid. The long axis of the os magnum is almost at right angles with that of the radius, and lies in an antero-posterior plane. The large amount of the cartilage on the head of the os magnum exposed in front is remarkable; and also characteristic of this position is the extensive area of the articular facet on the unciform bone for the pyramidal not in use.
4. An extensive hollow is formed between the two rows of carpal bones posteriorly.
5. Both on the superior and on the inferior surfaces of the scaphoid bone articular cartilage is exposed posteriorly, the amount in each situation being about equal.
6. A very small portion of the lunar bone is seen from behind.
7. The furrow on the radial margin of the carpus, between the trapezium, trapezoid, and scaphoid bones, is partially closed, and on the ulnar side a much smaller interval is found between the unciform and pyramidal bones.

Explanation of some of the Changes.

The small amount of ulnar flexion present is just that which is possible at the radio-carpal joint. If the relationships of the bones at the mid-carpal joint seen in this position be compared with those found in the "straight position" (compare figs. 1 and 11), it will be noticed that their relative position to one another is rather similar. For example, a similar amount of the articular surface of the unciform for the pyramidal bone is not in use, and a gap exists between the unciform and lunar bones in each case. The unciform cannot touch the lunar in full dorsiflexion, because the scaphoid bone is completely dorsiflexed. It will be remembered that in ulnar flexion the scaphoid bone requires to be dorsiflexed, and hence ulnar flexion becomes impossible in full dorsiflexion. The effect of the muscles which produce ulnar flexion is to press the head of the os magnum against the scaphoid bone. It follows therefore that if full dorsiflexion be not present, a limited amount of ulnar flexion is possible at the mid-carpal joint.

2. The change in the direction of the long axis of the scaphoid is due to the tension of the ligaments uniting it to the trapezium and trapezoid bones.

3. The dorsal flexion of the distal row causes the upper ends of these bones to project forward.

Only a brief account of the remaining preparations will be given.

Right Wrist-joint in Semi-volar and Ulnar Flexion.¹

The chief differences between this specimen and that of full palmar flexion are due mainly to the greater amount of ulnar flexion present. Owing to the lesser degree of palmar flexion, a much smaller area of the inferior articular surface of the radius is exposed in front. The tubercle of the scaphoid is not pushed quite so far up, and it lies below the lower edge of the radius. As in ulnar flexion the pyramidal bone is found on a plane anterior to the unciform, and the unciform has its articular facet for the pyramidal bone completely covered by the latter. The view of the dorsal surface so resembles that seen in complete palmar flexion that a further description is unnecessary.

Semi-palmar and Radial Flexion.

Seen from the front (fig. 13).—The position of the tubercle of the scaphoid is remarkable. It lies in front of the lower end of the radius. In

¹ This specimen differed so very slightly from the specimen of complete palmar flexion, that it was considered unnecessary to reproduce the drawings.

no other movement of the joint does it attain such a superior position. This is due to the fact that in both palmar and radial flexion of the wrist palmar flexion of the first row of carpal bones occurs. A part of the inferior surface of the radius is exposed anteriorly in this position of the wrist, but less than in complete palmar flexion. At the mid-carpal joint a very important change is found in the articulation between the



FIG. 13.—Left wrist-joint in semi-volar and radial flexion, seen from the front.

Amount of volar flexion = 20°.
Amount of radial flexion = 10°.



FIG. 14.—Left wrist-joint in semi-volar and radial flexion, seen from behind.

Amount of volar flexion = 20°.
Amount of radial flexion = 10°.

scaphoid, trapezium, and trapezoid bones. The latter two bones have been drawn well back, pushing the scaphoid forwards so that a considerable portion of the inferior facet on the scaphoid is free and can be seen from the front. The apex of the unciform has retreated far from the lunar bone, and this allows the head of the os magnum to articulate with the pyramidal bone (*Jour. Anat. and Phys.*, vol. xli. p. 121). A large amount of the articular facet on the unciform for the pyramidal bone is not in use.

Seen from behind (fig. 14).—We note the extensive area of the superior

articular facet on the scaphoid bone out of play, and the marked palmar flexion of the remaining bones of the first row. In this position the trapezoid, trapezium, and scaphoid bones meet exactly, and this condition was not found in any other position of the wrist-joint. The scaphoid bone is accurately adapted to the os magnum. The head of the os magnum



FIG. 15.—Right wrist-joint in semi-dorsal and ulnar flexion, seen from the front.

Amount of dorsal flexion = 30° .
Amount of ulnar flexion = 35° .



FIG. 16.—Right wrist-joint in semi-dorsal and ulnar flexion, seen from behind.

articulates with the pyramidal, and the interval between the pyramidal and the unciform bones is well marked, these bones failing to meet at the ulnar border of the carpus.

Semi-dorsal and Ulnar Flexion.

Seen from the front (fig. 15).—The appearance of the scaphoid very much resembles that seen in fig. 11. The tubercle has been drawn downwards as far as possible. The unciform is permitted to glide upwards and

backwards on the pyramidal, pushing the latter bone forwards, and this allows ulnar flexion at the mid-carpal joint to take place.

Seen from behind (fig. 16).—The gap between the unciform and pyramidal bones is almost closed.



FIG. 17.—Left wrist-joint in semi-dorsal and radial flexion, seen from the front.
Amount of dorsal flexion = 25 .
Amount of radial flexion = 20 .



FIG. 18.—Left wrist-joint in semi-dorsal and radial flexion, seen from behind.

Semi-dorsal and Radial Flexion.

Seen from the front (fig. 17).—The scaphoid is well dorsiflexed, but its long axis is not in line with that of the radius. The ulnar end of its superior articular surface is in contact with the antero-posterior ridge on the inferior surface of the radius. The greatest amount of radial flexion possible at the radio-carpal joint has taken place. At the mid-carpal joint, only a slight amount of radial flexion can take place. Owing to the scaphoid bone being dorsiflexed, the trapezium and trapezoid bones cannot be drawn upwards towards the styloid process of the radius as far as is

necessary for complete radial flexion, and the head of the os magnum and the narrow superior extremity of the unciform cannot move sufficiently to the ulnar side to allow them to articulate with the inferior facet on the pyramidal bone (Part I., p. 121). The upper extremity of the unciform becomes separated from the lunar, and a space is left between them similar to that which was noticed in the description of the articulations of the carpal bones in the straight position of the wrist (Part I., p. 113). These facts explain why radial flexion of the wrist-joint is so limited when any degree of dorsiflexion is also present.

Seen from behind (fig. 18).—The unciform and pyramidal bones are out of contact, and the large amount of the lower articular facets of the scaphoid bone, which are exposed posteriorly, confirms the conclusions arrived at in the previous paragraph.

A study of the specimens figured in this communication shows that the relationship of the carpal bones to one another is not only in many situations of a rather complicated character, but also that this relationship varies in many cases with every position of the joint. Between the carpal bones in a few situations (*e.g.* between the trapezium and trapezoid, between the trapezoid and os magnum, and between the pyramidal and lunar), no movement could be detected in any position of the wrist. In other situations (*e.g.* between the unciform and os magnum, and between the semi-lunar and scaphoid bones), a very limited amount of movement takes place in certain positions. In other situations the movement at the different joints (considering the size of the carpal bones) is of a most extensive character, and, as a rule, in these situations some articular cartilage is always visible either from the front or from the back. An attempt has been made to show that in the extreme positions of the wrist the movement is brought to an end by the various forces acting directly or indirectly on the scaphoid bone.

A BRAIN WITH COMPLETE ABSENCE OF THE CORPUS CALLOSUM. By JOHN CAMERON, M.D., D.Sc., F.R.S.E., *Senior Demonstrator of Anatomy, University of Manchester.*

I AM indebted to Professor Young for having kindly placed at my disposal the brain which forms the subject of this communication. The specimen has lain in the Anatomy Department of the University of Manchester for several years with the membranes intact, so that the records of the case have been unfortunately entirely lost. The brain was handed over to two of the students for dissection, the absence of the corpus callosum not being detected until the upper part of the left hemisphere had been removed. On a superficial study the specimen exhibited no exceptional features beyond those usually associated with deficiency of the corpus callosum. A closer examination of the limbic lobe, however, disclosed several interesting features which were considered worthy of being placed on record.

In a certain proportion of the cases of absence of the corpus callosum, the deficiency has been only a partial one. Thus, of the thirty cases published up to 1888, Bruce (2) found that entire absence occurred only in fifteen of these. In the case at present under consideration the corpus callosum was completely absent.

The main interest in this specimen is centred in the commissural structures which are developed in association with the lamina terminalis. Thus, in addition to the absence of the corpus callosum, the two lateral halves of the fornix are not united together by transverse commissural fibres, but are merely connected by an exceedingly thin semi-transparent membrane. The "fore-and-aft" fibres of the fornix are therefore alone represented. The posterior pillars pass to the uncus as usual. The anterior pillars, however, show a difference of arrangement on the two sides. For example, on the right side, by far the greater number of the fibres pass in front of the anterior commissure, very few coursing posteriorly to this structure. On the left side, most of the fibres go behind the commissure, though a considerable number pass in front (fig. 4). The corpora mammillaria are well formed on both sides.

From the outer margin of the band of fibres representing each lateral half of the body of the fornix there is an extension outwards of the thin membranous sheet already referred to (fig. 3). This can be readily traced

to its termination by blending with the cortex of the callosal convolution at the bottom of what corresponds to the callosal sulcus (fig. 4). It accordingly represents the *lamina terminalis*. When traced forwards in the middle line it blends with the anterior commissure (fig. 2). From the latter structure it passes downwards as the lamina cinerea, which is connected as usual with the optic commissure (fig. 2). The lamina has thus retained its embryonic attachments in this specimen.

Two other longitudinal or "fore-and-aft" systems of fibres run close to

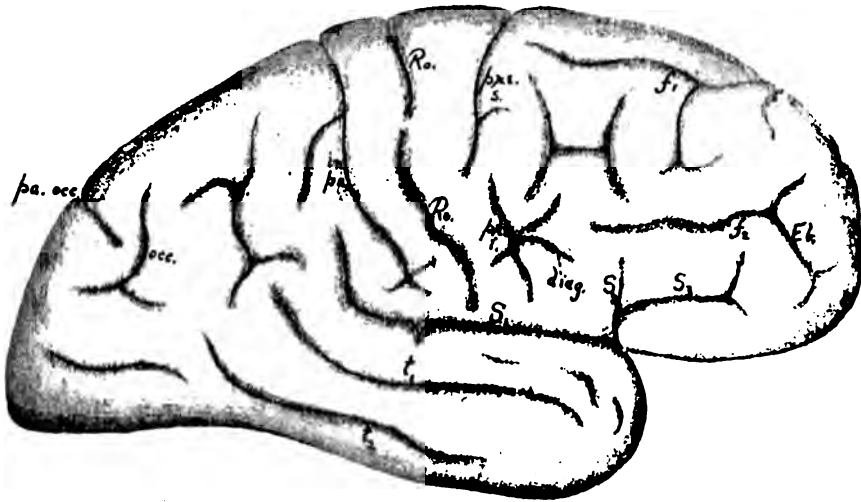


FIG. 1.—Outer surface of right hemisphere (three-fifths natural size).

the outer side of the fornix, lying more or less parallel to the latter. The band of fibres next to the fornix, when traced anteriorly, blends with the precommissural fibres of the anterior pillar, more particularly on the right side, the resultant band passing across the anterior perforated spot to the uncus and the temporal pole. Some of the fibres can also be followed to the mesial olfactory root (figs. 2 and 3). Posteriorly, this second system of longitudinal fibres remains distinct from the posterior pillar of the fornix, though it overlaps the latter slightly (fig. 2). It can be traced to its junction with the posterior extremity of the dentate convolution, the latter structure being more prominently developed than usual. This band, from its anterior and posterior connections, represents the *striae longitudinales* (both mesial and lateral). The band of Giacomini is only faintly discernible.

The third or most externally placed band of fibres lies close to the line of junction of the lamina with the callosal convolution. It passes anteriorly to the anterior perforated spot, on the surface of which it gradually becomes lost. At its posterior extremity it becomes intimately associated with the longitudinal striae (fig. 3). This close connection does not exist long, however, for the united band soon bifurcates again into its two constituent elements, those fibres belonging to this outer set ending in the hippocampal convolution close to the isthmus (figs. 2 and 3). The attachments of this

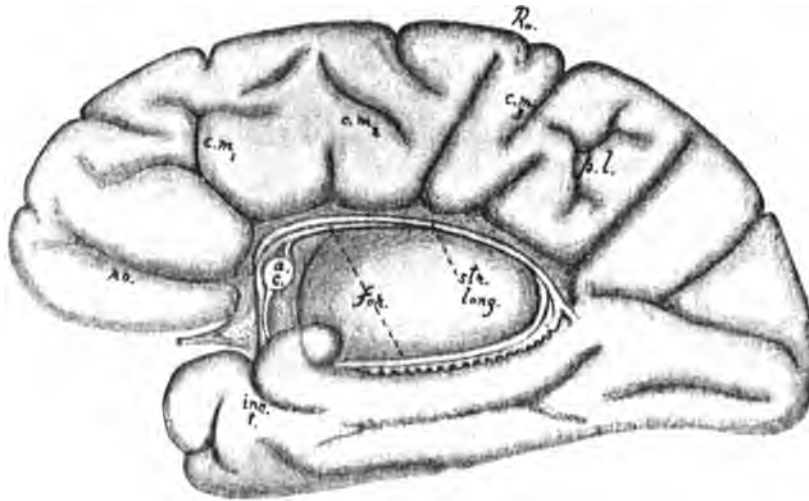


FIG. 2.—Mesial surface of right hemisphere (three-fifths natural size).

outer band correspond to those of the *cingulum*, which structure it apparently represents.

The tissue intervening between these three groups of longitudinal fibres is thin and translucent, and apparently almost devoid of nervous elements. That portion connecting the two halves of the fornix was so delicate that most of it came away with the pia mater. The remains could, however, be recognised as a ragged fringe attached to the inner margins of the fornix bands, which floated out on immersing the brain in fluid (fig. 3).

This intimate association of the fornix, longitudinal striae, and cingulum with the lamina terminalis¹ suggests that in this case they had all been

¹ The employment of this term for the adult brain is, I think, justifiable in the present specimen.

developed in that structure. The close relationship which the fornix bears to the lamina has been pointed out by Elliot Smith (15 *et seq.*). A difficulty arises, however, in regard to the genesis of the longitudinal striæ and cingulum. The usual acceptance is that the former represent part of an aborted convolution belonging to the limbic lobe (14). The intimate relationship which the longitudinal striæ bear to the fornix in this specimen has, however, led me to accept Cunningham's suggestion (3 and 4), that these striæ are simply an outlying part of the fornix system. Both striæ and fornix, it may be noted, normally contain a system of longitudinal fibres *plus* a certain amount of grey matter. Thus, in some monkeys there is a band of grey matter running along the upper surface of the fornix, forming the so-called *gyrus infracallosus* (14), while the thin lamina of grey matter in relation to the striæ is continuous with the grey matter of the callosal gyrus. Zuckerkandl (22 and 23) for this reason regarded these striæ, together with their grey matter, as a degenerate convolution (*gyrus supracallosus*). When Zuckerkandl gave effect to this acceptance of the nature of these striæ, the lamina terminalis of His (10) had not received the recognition now so freely accorded to it, so that another explanation of the presence of the above grey matter is possible in the light of our present knowledge of this embryonic structure. Thus, if the lamina terminalis of a typical mammalian embryo (*e.g.* rabbit of the 13th day) be studied, it will be found to be as richly endowed with neuroblasts as the neighbouring hemisphere wall, the structural appearance being exactly similar in both. One can readily trace the separation of the cell-elements in the lamina terminalis into groups by the development of the commissural systems. As a result of recent work in this direction, I am convinced that the grey matter in association with the striæ and fornix is derived from the lamina terminalis, and not introduced from any external source. This question will be fully discussed in a future communication.

The close association of the fibres of the cingulum with the striæ in this specimen tempts one to include this band also as an outlying part of the fornix system. It certainly appears in this instance to be an intimate part of the lamina terminalis, a fact which is suggestive of its origin in the latter. The discussion of this question will likewise have to be postponed for the present.

It is of interest to note that absence or deficiency of the corpus callosum is apparently associated with absence also of the septum lucidum. At least this has been so in the cases recently recorded by Douglas-Crawford (6), Elliot Smith¹ and Patten.¹ Bruce (2), however, in his specimen figures an area which he regards as representing the septum lucidum. The

¹ Exhibited at the Summer Meeting of the Anatomical Society, May 1906.

septum proved to be absent in the present case also. This fact will be found of great significance when considered in association with the development of the septum lucidum, as will be brought out more fully in a subsequent paper.

The probable course of development in this specimen is best appreciated by a study of the developing fore-brain, both in animals which possess a corpus callosum, and in those (such as birds) in which this commissure is absent. In the human embryo, as in lower animals, the roof-plate of the

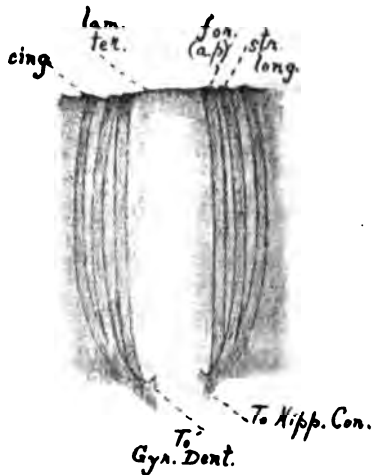


FIG. 3.—Arrangement of longitudinal bands in lamina terminalis.

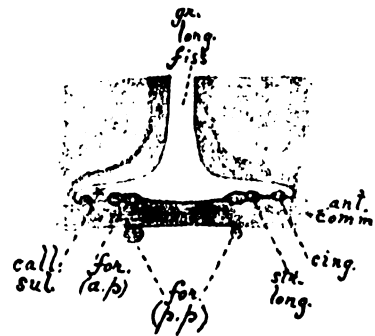


FIG. 4.—Horizontal section through anterior commissure and great longitudinal fissure.

fore-brain, in front of the epiphysis and superior commissure, becomes a simple epithelial structure as far forward in the middle line as the lamina terminalis. Practically the whole of this epithelial roof becomes invaginated to form the covering of the velum interpositum.¹ In birds (*e.g.* the chick) this epithelial transformation of the cerebral roof-plate goes a distinct step further. The epithelial transformation has been very extensive in this specimen, for it has occurred as far forward in the middle line as the anterior commissure (fig. 2), so that we have here a reversion to a lower type of development, involving not only the fore-brain roof-plate, but also a considerable part of the lamina terminalis.

Douglas-Crawford (6) has furnished a full account of the convolutions in his case. I shall therefore be content to refer to a few points of special

¹ The *paraphysis* is developed from this roof in front of the velum.

interest. In the present specimen the convolutions and sulci were studied to best advantage on the right side, owing to the upper part of the left hemisphere having been removed before the condition was recognised. They do not exhibit to any marked degree the radiating arrangement which has been described by Cunningham (3 and 4) in brains with absence of the corpus callosum. The most prominent features are the simple arrangement of the convolutions, as also the number and fantastic shape of certain isolated sulci, especially on the outer surface. Two of the latter are particularly prominent, and are H-shaped. One is in the right middle frontal gyrus, and the other in the parietal lobe immediately above the tail of the right parallel fissure (fig. 1). Another sulcus, exhibiting striking

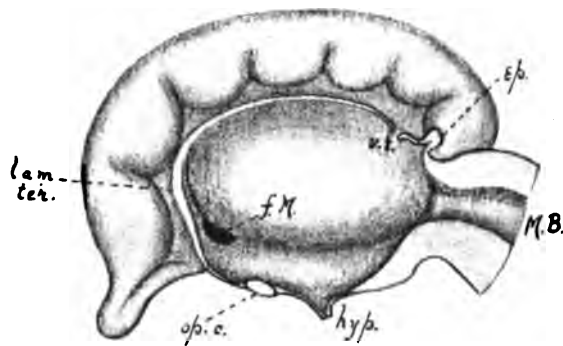


FIG. 5.—Mesial aspect of right hemisphere of 6.5 cm. fetus (enlarged $2\frac{1}{2}$ times).

features, is situated in front of the lower part of the right fissure of Rolando, and consists of a group of five radiating sulci. When examined carefully it may be recognised as consisting of the inferior precentral sulcus blended with the diagonal sulcus. The right fissure of Rolando consists of an upper and a lower limb. The vertical part of the intra-parietal sulcus is unusually extensive, and is continuous round the superior border with a sulcus on the mesial aspect to be subsequently described.

The limiting sulcus of Reil is deeper than usual, while the gyri of the insula are prominently marked.

The sulci on the mesial aspect of the hemisphere possess a radiating arrangement, as described by Douglas-Crawford (6) and Bruce (2). It is interesting to compare these with the sulci in the same region of the fetal brain, as Bruce (2) has previously done (figs. 2 and 5). It will be found that, prior to any great advance in the formation of the corpus callosum, the so-called temporary sulci are arranged in a radiating fashion. Fig. 5

shows the appearance presented by the mesial aspect of the right hemisphere of a 6.5 cm. human foetus. By the end of the sixth month the corpus callosum has become well developed, the mesial surface of the hemisphere as a result tending to be compressed between the corpus callosum and the cranial vault. This causes obliteration of these temporary radial sulci, and the formation of a fresh set of sulci which lie more or less parallel to these opposing surfaces. The calloso-marginal sulcus is one of the most important of these permanent sulci, and is usually developed in three parts—anterior, middle, and posterior (13). These are shown in fig. 6, which is the mesial aspect of the hemisphere of a foetus at the end of the sixth month. On turning to the specimen (fig. 2), one can recognise the effect of the absence or deficiency of one of the forces causing the com-



FIG. 6.—Mesial aspect of right hemisphere (foetus at end of sixth month).

pression of the mesial surface of the growing hemisphere referred to above. There is the suggestion of an attempt at forming the anterior and middle portions of the calloso-marginal sulcus (*c.m.*₁ and *c.m.*₂). The upper part of the radial sulcus lettered *c.m.*₃ is in the site of the posterior portion of the calloso-marginal sulcus; but one cannot state definitely whether or not this represents the posterior extremity of the permanent fissure. This radial sulcus is continuous round the mesial border of the hemisphere with the upper end of the intraparietal sulcus, the two together forming a very extensive fissure. The rostral sulcus will be observed to be well developed, while the incisura temporalis is particularly prominent (fig. 2). The calcarine and internal parieto-occipital fissures appear in fig. 2 to be in direct continuity; but on opening them up the gyrus cuneus was found just within, and therefore almost level with the surface. In Crawford's case (6) the gyrus cuneus comes to the surface, and separates the above fissures—a condition which, indeed, appears to be usually found in brains with absence of the corpus callosum.

The whole of the rhinencephalon is unusually well developed, so that the roots of the olfactory peduncle can be traced with ease to their respective destinations. It is rather interesting to note that this undue prominence of the rhinencephalon is associated with entire absence of the transverse commissural fibres of the fornix, a fact which suggests that these fibres do not form a very important, far less an essential, part of the rhinencephalon.

The cerebral sulci are on the whole deeper than in normal brains, the average being 14 or 15 mm. instead of the normal 10-12 mm. (12). Some are exceptionally deep. Thus the lower segment of the right Rolandic fissure is 20 mm. deep at its middle, while the depth of the post-central sulcus is as much as 21 mm.

Absence of the corpus callosum is usually found associated with a tendency to abnormal size of the ventricular cavities, almost amounting to a hydrocephalic condition. Indeed, Turner (21) has suggested that this may explain the arrested development of the corpus callosum. In the present specimen, in addition to a complete failure of those fibres of the corpus callosum which cross the mesial plane, there is apparently almost total absence of those portions of the commissure which, under normal conditions, occupy each hemisphere and constitute the roof of the lateral ventricles. Consequently the latter cavities are decidedly more capacious than normal. The increased capacity, from this point of view, is thus, partly at least, the result of a general deficiency of the corpus callosum; though this conclusion does not entirely put out of court the possible existence of a concomitant hydrocephalic condition.

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- (16) SMITH, G. ELLIOT, "The Relation of the Fornix to the Margin of the Cerebral Cortex," *Jour. Anat. and Phys.*, vol. xxxii., 1898.
- (17) SMITH, G. ELLIOT, "Further Observations upon the Fornix," *Jour. Anat. and Phys.*, vol. xxxii., 1898.
- (18) SMITH, G. ELLIOT, "The Origin of the Corpus Callosum: a Comparative Study of the Hippocampal Region of the Cerebrum of Marsupialia and certain Cheiroptera," *Trans. Linn. Soc. Lond.*, vol. vii., part 3, 1897.
- (19) SMITH, G. ELLIOT, "Further Observations on the Anatomy of the Brain in the Monotremata," *Jour. Anat. and Phys.*, vol. xxxiii., 1899.
- (20) SYMINGTON, J., "The Cerebral Commissures in the Marsupialia and Monotremata," *Jour. Anat. and Phys.*, vol. xxvii., 1893.
- (21) TURNER, SIR WM., "A Human Cerebrum imperfectly divided into two Hemispheres," *Jour. Anat. and Phys.*, vol. xii., 1878.
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ABBREVIATIONS.

a.c.	anterior commissure.	gr.long.fiss.	great longitudinal fissure.
ant.comm.	anterior commissure.	gyr.dent.	gyrus dentatus.
call.sul.	callosal sulcus.	hyp.	hypophysis.
c.m. ₁ , c.m. ₂ , c.m. ₃	calloso-marginal sulcus.	inc.t.	incisura temporalis.
cing.	cingulum.	in.pa.	intraparietal sulcus.
diag.	diagonal sulcus.	lam.ter.	lamina terminalis.
ep.	epiphysis.	M.B.	mid brain.
Eb.	sulcus of Eberstaller.	occ.	pars occipitalis.
for.	fornix.	op.c.	optic commissure.
for.(a.p.)	precommissural fibres of anterior pillar of fornix.	pa.occ.	parieto-occipital-fissure.
for.(p.p.)	postcommissural fibres of anterior pillar of fornix.	p.l.	post-limbic fissure.
f.M.	foramen of Monro.	pre.s.	superior precentral sulcus.
f. ₁	superior frontal sulcus.	pre.i.	inferior precentral sulcus.
f. ₂	inferior frontal sulcus.	Ro.	fissure of Rolando.
		ro.	rostral sulcus.
		S. ₁ , S. ₂ , S. ₃	fissure of Silvius.
		t. ₁	superior temporal sulcus.
		t. ₂	inferior temporal sulcus.

A CASE OF FUSION OF THE SEMILUNAR AND CUNEIFORM BONES. By ADAMS A. M'CONNELL, B.A., *Trinity College, Dublin.*

IN the October number of the *Journal of Anatomy and Physiology*, Mr Douglas E. Derry gives an interesting note on the occurrence of fusion of the semilunar and cuneiform bones. He points out that this abnormality is relatively much more common in negroes than in white men. He has collected information regarding two cases, described by himself, and references to four others, and he notes that of the total recorded cases all occurred in negroes. The editors, in a footnote, give a reference to a case of fusion of the semilunar and cuneiform bones, published in the same Journal, vol. xvii. p. 255, by Dr R. J. Anderson, who also refers to a

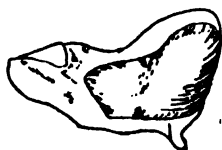


FIG. 1.

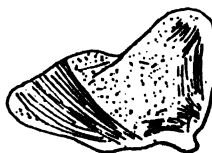


FIG. 2.

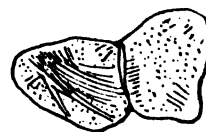


FIG. 3.

similar case described by Wagner. Professor Anderson has kindly informed me that his specimen was found in the carpus of a white man.

In the Anatomical Department of Trinity College, Dublin, there is a right carpus of a male subject, presumably Irish or Anglo-Irish, which shows complete fusion of the semilunar and cuneiform bones. A vertical transverse section through the combined semilunar and cuneiform bones demonstrates the absolute continuity of the cancellous tissue.

Fig. 1 gives a view of the upper surface of the specimen. The facet for the pisiform bone is seen in part.

Dr Walter C. Stevenson very kindly took several X-ray photographs of the specimen, for which I am greatly indebted to him.

One of these photographs is represented diagrammatically in fig. 2. It shows the continuity of the cancellous tissue, and also the arrangement of the lamellæ in the compound bone. For purposes of comparison an X-ray photograph of two normal bones is represented in fig. 3.

Neither the palmar nor the dorsal surfaces shows any indication of the

line of the normal articulation between the bones. The entire inferior surface is articular and uninterrupted by any marking. The radial side of the superior surface shows a large smooth area, the articular cartilage on which is divided by a faint roughness running in an antero-posterior direction into two parts, one corresponding to the facet on the lower surface of the radius, and the other to the under aspect of the triangular fibro-cartilage. This articular area occupies about two-thirds of the superior surface, which is rough to the ulnar side of it.

In the carpus of the left hand the bones were normally disposed, and no fusion of the semilunar and cuneiform bones was present. Considering the rarity of fusion of the semilunar and cuneiform bones, and the fact that this abnormality is relatively more common in negroes, it seems advisable to place as many cases on record as possible, and it is on this account that the present communication is brought forward.

A METHOD FOR DETERMINING THE POSITION OF THE BASE
OF THE EYE-SOCKET. By EVELYN JOHN EVATT, *Lecturer in
Applied Anatomy, University College of South Wales and Mon-
mouthshire, Cardiff.*

ONE meets with frequent references in works on craniology to the so-called obliquity of the eye-socket; but as there does not seem to be any recognised method for determining the position of the eye-socket, the object of the following paper is to suggest one.

Let us take the adult human eye-socket as our type.

The mouth, or that part of the eye-socket which appears on the surface of the skull, is its *base*, and the margin which surrounds the base may be termed the *rim*.

The upper, outer, and lower segments of the rim are usually at once recognisable. A difficulty, as W. Turner has pointed out, in the case of the male Australian skull may present itself in sharply defining the outer boundary (*Challenger Reports*, 1873-76, vol. x., "Report on Human Crania," p. 32).

A careful scrutiny of the anterior surface of the outer segment reveals the presence of a slight ridge which projects in front of the rounded contour of this part. This ridge is invariably found to run continuously into the upper and outer part of the rim, and can be rendered more evident by laying the lead of a pencil flat on the anterior surface of the outer boundary and drawing it along: a sharp line is thus marked on this, the most salient part of the rim. This pencil-marked ridge may be regarded as the mathematical limit of the outer boundary.

In certain animals, notably in carnivores, the external or posterior segment of the rim is wanting, there being no osseous union between the frontal and the zygoma. In these cases, points either on the orbital processes of the zygoma, or on the post-orbital processes of the frontal, whichever lie nearest the horizontal plane through Flower's *lacrimal points* (see below), may be taken to represent the outer limit of the rim.

"In frugivorous bats the lacrimal foramen is situated outside the margin of the orbit" (Flower, *Mammalian Osteology*, third edition, p. 176). This condition occurs also in a great many other animals, so that the lacrimal crest in these cases comes to form the inner segment of the rim.

In primates, and particularly in Man, the lachrymal crest is continuous, with a well-defined ridge on the frontal bone; therefore, on morphological grounds, this *orbital crest* of the frontal bone, together with the lachrymal crest, may be regarded as the upper and inner segment of the rim. The bones entering into the formation of the rim are the frontal, malar, superior maxilla, and the lachrymal.

In order to determine the position of the base of the eye-socket, let us take four points on the orbital rims, two of these on the inner segments, where the lachrymal crests meet the frontal-lachrymal sutures (Flower's lachrymal points), and two on the outer segments, transversely opposite the first two. These usually fall on the malar bone, immediately below the fronto-malar suture, and may be conveniently called the *malar points*. Now, knowing the distance between these several points, one can construct a quadrilateral (fig. 1).

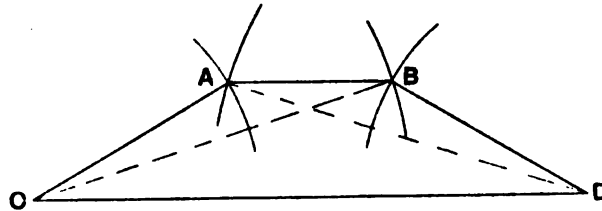


FIG. 1.—Method of plotting out the figure from given measurements.

In this figure A and B represent Flower's lachrymal points, and C and D the malar points. The distance AB is the *inner interorbital* width, CD the *outer interorbital* width; whilst AC and BD are the transverse widths of the orbital bases.

Since these lengths are not sufficient to enable us to determine the size of the angle contained between the base and the coronal plane (outer interorbital width), owing to the occasional asymmetry in the position of the two bases, it is necessary to ascertain in addition the lengths AD and BC; the figures may be then constructed in the following manner (fig. 1):—

With centres C and D, which are the ends of the outer orbital width, describe circles with radii CA and DB respectively; and with centres D and C, and radii DA and CB respectively, describe circles. Let these circles cut at A and B; join CA, AB, BD, and lastly, CB and DA.

The angle ACD or BDC may be termed the *basic angle*, and is a measure of the so-called obliquity of the eye-socket.

The value of the angle, e.g., ACD in the triangle ACD, may be deter-

mined by the use of the ordinary trigonometrical formula

$$\sin \frac{C}{2} = \sqrt{\frac{(s-a)(s-d)}{ad}},$$

or by direct measurement of the angle in the figure.

The accompanying figures will show at a glance how the position of the bases with reference to a coronal plane may be graphically represented (fig. 2, *a, b, c, d*).

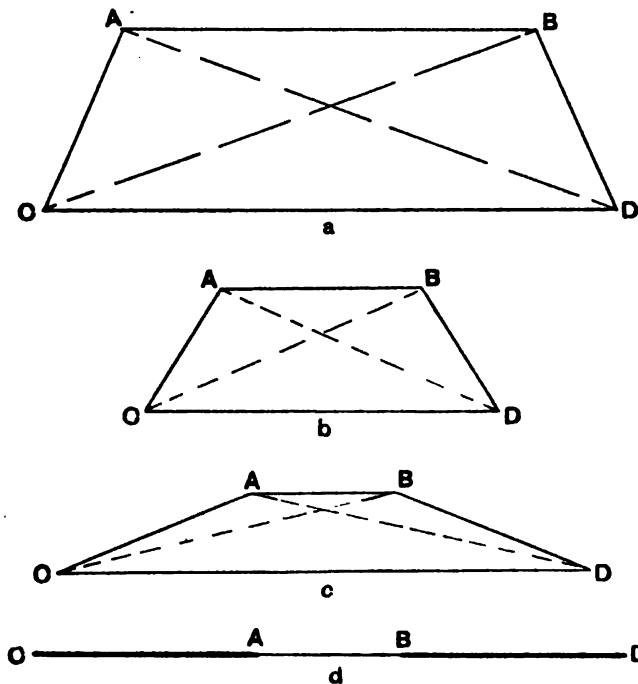


FIG. 2, *a, b, c, d*.—Plotted out from measurements obtained from *a*, a sheep; *b*, a dog; *c*, a negro; *d*, an orang-utan. The basic angles ACD are $66^{\circ} 52'$, $57^{\circ} 52'$, $21^{\circ} 18'$, and 0° respectively. Two-thirds actual size.

I have examined the eye-sockets of 105 adult human skulls of different races and sexes, but until a considerably greater number have been examined, I do not feel justified in attempting to formulate any statements that may be of morphological interest. Still, as the position of the eye-socket may possibly prove to be a factor in the classification of skulls, in anticipation the eye-socket may be defined as *Ithybasic* (*ἰθύς*, forwards), *Mesobasic* (*μεσός*, middle), *Loxobasic* (*λοξός*, slanting), according to the degree of forward projection of the base of the eye-socket.

In conclusion, it may be mentioned that the greatest basic angle which I have so far observed in adult human skulls was in the case of a male negro, and it amounted to $21^{\circ} 18'$. Fig. 2, *c* has been plotted out from measurements obtained from this skull.

Three of the number were true ithybasic, that is, the bases were at right angles to the mesial plane and coincided with the coronal plane, as in fig. 2, *d*.

The basic angle of the eye-socket in the skull of the one microcephalic idiot which I have had an opportunity of examining, was $15^{\circ} 8'$; it is therefore not inconsistent with the human type, and is not anthropoid.

The anthropoid eye-socket is ithybasic (fig. 2, *d*), and not infrequently the basic angle is re-entrant.

THE LATERAL FIXATION OF THE CERVIX UTERI. By ELLA
G. A. OVENDEN, M.D., *Assistant Demonstrator in Anatomy,*
Women's Department, Medical School, Trinity College, Dublin.

IN a paper published in the *Archiv f. Gynækologie* in 1895¹ Mackenrodt investigates the factors at work which hold the uterus in its normal position of anteversion and antelexion. In the course of this paper he lays great stress on the action of a band of connective tissue, which he calls the "ligamentum transversalis colli." As this ligament is not described as such in any of the usually read text-books of anatomy, and in only a few of the text-books of gynæcology, and appears to be gaining in interest with those who have been working in the German Schools, I have been led to carry out an investigation to see whether it might lay claim to the prominent position which Mackenrodt has given it.

The points which Mackenrodt brings out in his paper are the following:—

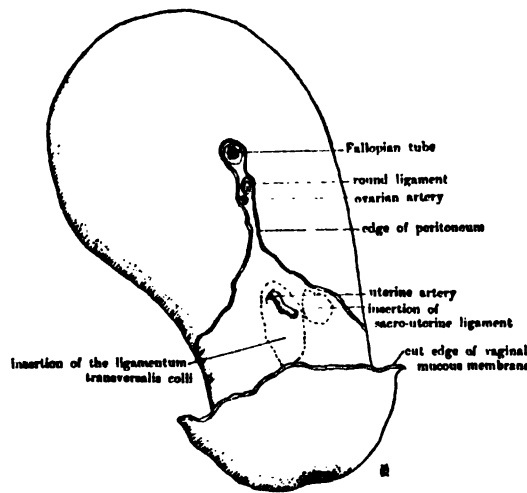
1. The lower opening of the pelvis is closed by the pelvic fascia, which sends firm bands to the cervix and vagina.
2. The *cervix* is held fast in its embryological position by ligaments, and the normal anteversion and antelexion takes place by the bending of the cervix—not the corpus.
3. The uterine *body* is kept in position by its own weight and intra-abdominal pressure—not by ligaments.
4. There are fibres coming from the pelvic fascia to the side of the cervix, which are sharply to be defined from the sparse connective tissue fibres between the layers of the broad ligament. These form a band that is the chief means of holding the uterus in position.

Mackenrodt denies the statements of Schultz, Schroeder, and Hodge, who all agree that the ligamentum rotundum has an influence in maintaining the anteverted position of the uterus. He supports his words by stating that he has often, in the course of a laparotomy, resected portions of the round ligament and retroverted the uterus experimentally; but that he has always found on subsequent examination—in the case of a healthy non-pregnant uterus—that the organ would right itself and be found anteverted again. None of the three authorities just mentioned lay any weight on the work

¹ "Ueber die Ursachen der normal u. path., Lagen des Uterus," *Archiv f. Gyn.*, xlviii. 393–421, 1895.

done by a band of connective tissue running from the walls of the pelvis to be attached to the cervix; nor do Nagel or Tschausow, who attribute the curve of the uterine body to the fact that it has grown in the limited room of the foetal pelvis, the curve of which has given it the anteverted and anteфлекed position.

In addition to the ligaments usually described, viz. the broad ligaments, the anterior and posterior ligaments, the sacro-uterine ligaments and the round ligaments, I wish to show that there is another ligament, easily demonstrated anatomically, and, according to Mackenrodt, of great physiological importance



Side view of uterus (as removed by vaginal hysterectomy), showing the insertion of the ligamentum transversalis colli of Mackenrodt.

in maintaining the normal position of the uterus. Mackenrodt defines it as follows:—"At the side of the vertebral column the pelvic fascia can be seen to give rise to a strong band which is inserted into the side wall of the collum uteri. . . . The small weak centre of areolar tissue, between the folds of the peritoneum in the broad ligament, is sharply to be defined from this fibrous band, which begins at the internal os, and springs from the pelvic fascia. We speak, therefore, of the broad ligament only as the part covering the uterine body, and call the lateral band to the collum the *ligamentum transversalis colli*. It is the chief means of fixation of the uterus, and carries in its upper margin the chief artery—the *arteria uterina*."

J. Whitridge Williams, in his text-book on Midwifery, is one of the few
VOL. XII. (THIRD SER. VOL. II.)—JULY 1907.

who mention the ligament. He says—"At the lateral margin of the uterus the peritoneal covering of the broad ligament is reflected on the side of the pelvis. The inferior margin, which is quite thick, is continuous with the connective tissue of the pelvic floor. Through it pass the uterine vessels. Its lower portion—the 'cardinal ligament' of Kocks, or the 'ligamentum transversalis colli' of Mackenrodt—is composed of dense connective tissue, which is firmly united to the supravaginal portion of the cervix."

There can be no doubt that in the dissection of the pelvis this band forms an easily defined and striking object. Between the layers of the broad ligament, at a level with the body of the uterus, there is very little connective tissue to be found. The two layers of peritoneum lie upon each other, separated only by some loose subperitoneal areolar tissue, the round ligaments, the Fallopian tubes, etc. At the level of the cervix, however, a thick band can be felt between the two layers of peritoneum. It is wedge-shaped in section; the apex of the wedge is directed upwards and is just about the level of the point of entrance of the uterine artery. Traced to its distal attachments, this band is found to be formed from strong fibrous connective tissue, continuous with that which surrounds the pelvic blood-vessels, and also that which comes through the sacro-sciatic notch. Some of the fibres appear also to be attached to the sides of the 3rd and 4th pieces of the sacrum.

The central attachment of this band is described by Mackenrodt as being the supra-vaginal portion of the cervix. It was suggested to me at the beginning of this investigation that this must be impossible, because during the operation for vaginal hysterectomy the uterus is cleared from all its attachments by merely stripping with the finger, after the vaginal mucous membrane has been cut. As far as I can make out, the ligament is inserted partly into the vault of the vagina and the lateral fornix, but also directly into the side of the uterus for a short distance below the point of entrance of the uterine artery (see figure). It constitutes the tissue which is generally clamped or tied along with the uterine artery in the operation for vaginal hysterectomy. Rather more than half the ligament, however, seems to be inserted into the lateral fornix and vault of the vagina. Certainly the whole mass is not—as Mackenrodt asserts—attached to the uterus. I cannot follow him either in his statement that the ligament comes from what he calls the "fascia pelvis"—if by this he means the visceral layer of the pelvic fascia—for, in spite of careful search, I could find no definite connection between the ligament and this layer, any more than between any two closely superposed planes of fascia. It appears chiefly to come, as I have described above, from the connective tissue round the uterine and iliac vessels. Both Emmet and Schauta have laid emphasis

on the importance of the part played by this pelvic connective tissue in maintaining the normal position of the uterus, though they did not ascribe it to a particular band.

The utero-sacral ligament blends with the band near its insertion into the uterus.

In microscopic sections the ligament is found to consist largely of fibrous tissue, through which are scattered a good many bundles of smooth muscle fibre, and which supports a fairly large number of veins and lymphatics, as well as the uterine artery.

Its action as regards the position of the uterus, according to Mackenrodt's idea, can best be explained by the fact that, coming as it does with the vessels, and from the postero-lateral part of the pelvic wall, it would hold the cervix firmly with a pull in a slightly backward as well as lateral direction, and this pull, acting with the other factors described before, *i.e.* the intra-abdominal pressure and the weight of the uterus itself, would tend to preserve the normal anteversion and anteflexion of the uterus.

The question is, then—Has this band as much right to the name of a ligament as the others which hold the uterus in position, and should it be described as a separate entity lying between the layers of the broad ligament? In the light of these investigations, I think it is worthy of a more important position than that which it has hitherto held.

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PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND

NOVEMBER 1906

THE ANNUAL GENERAL MEETING was held at King's College on Friday, 24th November 1906, at 3.30 p.m. Dr KEITH (Vice-President), in the absence of the President, occupied the Chair. There were present nineteen members and nine visitors.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were elected to the Offices and Council for the ensuing year:—

President.

ARTHUR THOMSON, M.A., M.B.

Vice-Presidents

A. KEITH, M.D.; JAMES MUSGROVE, M.D.; A. F. DIXON, M.B.

Treasurer.

F. G. PARSONS.

Secretaries.

WILLIAM WRIGHT, M.B., D.Sc. (England); ALEXANDER MACPHAIL, M.D. (Scotland); H. M. JOHNSTON, M.D. (Ireland).

Council.

C. ADDISON, M.D.; R. H. BURNE, B.A.; T. H. BRYCE, M.D.; D. J. CUNNINGHAM, M.D., F.R.S.; W. M'ADAM ECCLES, M.S.; E. FAWCETT, M.D.; R. J. GLADSTONE, M.D.; J. YULE MACKAY, M.D.; A. MACALISTER, M.D., F.R.S.; A. M. PATERSON, M.D.; J. P. PYE, M.D., D.Sc.; W. G. RIDWOOD, D.Sc.; ARTHUR ROBINSON, M.D.; J. SYMINGTON,

M.D., F.R.S.; G. D. THANE, LL.D.; PETER THOMPSON, M.D.; H. W. MARETT TIMS, M.D.; J. T. WILSON, M.D.; B. C. A. WINDLE, M.D., F.R.S.; A. H. YOUNG, M.B., LL.D.

Votes of thanks to the retiring President and Honorary Secretary were proposed and carried.

The Treasurer presented his Report for the year 2nd November 1905 to 2nd November 1906 as follows:—

<i>Receipts.</i>			<i>Payments.</i>		
	£	s. d.		£	s. d.
Balance, 2nd November 1905	72	6 7	Printing, etc.	20	12 6
Subscriptions in arrear (now paid)	25	15 0	Cost of illustrations	46	18 6
" for current year	41	9 9	<i>International Catalogue</i>	10	0 0
" in advance	4	4 0	Subsidy to <i>Journal of Anatomy</i>	25	0 0
Received for illustrations	14	16 8	Indexing <i>Journal of Anatomy</i>	35	0 0
Members' subscriptions to the			Members' subscriptions to the		
<i>Journal of Anatomy</i>	1	10 0	<i>Journal of Anatomy</i>	1	10 0
			Expenses, petty cash and sundries	2	14 9
			Balance at Bank, 2nd Nov. 1906	18	6 3
	£160	2 0		£160	2 0

7th November 1906.—Examined and found correct.

W. M'ADAM ECCLES, }
R. H. BURNE, } Auditors.

F. G. PARSONS,
Hon. Treasurer.

The Report was received, approved, and ordered to be entered on the minutes.

Professor GUGLIELMO ROMITI, of the Royal University of Pisa, was unanimously elected an Honorary Member of the Society.

Dr KEITH proposed, and Mr M'ADAM ECCLES seconded, "That the question of the Society's continuing to pay for the collection of material for the Anatomy Volume of the *International Catalogue of Scientific Literature*, and for the preparation of the Index of the *Journal of Anatomy and Physiology*, be remitted to the Committee of Management for consideration, with power to cease the payments at a convenient date if thought desirable."

An amendment that the words beginning "with power, etc.," be deleted, was proposed by Professor PATERSON and seconded by Professor YOUNG. The amendment was lost.

Dr KEITH having withdrawn his motion, Professor THOMPSON proposed, and Dr ADDISON seconded, "That this meeting authorises the Committee of Management to cease the contribution of funds towards the collection of material for the Anatomy Volume of the *International Catalogue*." The motion was lost.

Dr ADDISON next proposed, Dr KEITH seconded, and it was carried

unanimously, "That this meeting instructs the Committee of Management to provisionally refrain from entering into any arrangement for continuing the preparation of the Index of the *Journal of Anatomy and Physiology*, to consider if some more economical arrangement can be made, and to report at the next ordinary meeting of the Society."

The following communications were made:—

1. Professor PETER THOMPSON gave a description of a human embryo, 2.5 mm. in length, reconstructed by the wax-plate method.¹ He showed a series of lantern slides illustrating the form of the heart and the general arrangement of the various organs. Models of the brain, the heart and its endothelial tube, the alimentary canal, were also shown.

2. Professor A. H. YOUNG exhibited a heart from a man aged thirty-five years, exhibiting the rare anomaly of a single functional ventricle.¹ Further, there was a transposition of the large arterial trunks so that the transposed aorta arose from the right side of the common ventricle. During fetal life the arterialised blood must have passed from the placenta successively through the right and left auricles and been directed to the left part of the common ventricle. It would then pass to the right part towards the aorta, in its course intermixing with the caval venous blood from the right auricle. The course of the main blood-stream would tend to interfere with the complete development of the interventricular septum, and so there would be no formation of right and left ventricular chambers.

3. Professor A. M. PATERSON read a paper on *The Mechanical Supports of the Pelvic Viscera*.² Speaking of the pelvic fascia, he suggested that the term "visceral" pelvic fascia should be dropped altogether as confusing and misleading. The only viscera invested by pelvic fascia are the genito-urinary organs, the prostate, vesiculæ seminales and vasa deferentia in the male, and the vagina and urethra in the female: and these are invested and suspended by a special fold of the pelvic fascia for which he suggested the term suspensory ligament. The rectum is altogether free and separate from adhesions of the pelvic fascia; it lies loose in a special channel bounded in front by the suspensory ligament; it is clothed by extra-peritoneal tissue and is free to distend and collapse.

4. Dr C. A. HILL (introduced by Professor Paterson) gave an account of a prehistoric skeleton found in a cave at Litledale, Yorkshire.¹

¹ The paper is published in full in the April number of the *Journal of Anatomy and Physiology*.

² The paper is published in full in the January number of the *Journal of Anatomy and Physiology*.

JANUARY 1907

AN Ordinary Meeting of the Society was held on Saturday, 26th January, in the Medical School of the London Hospital.

The President occupied the Chair. There were fourteen members present and three visitors.

The minutes of the previous meeting were read and confirmed.

The Secretary read a letter from Professor Romiti thanking the Society for the honour they had bestowed upon him in electing him an Honorary Member.

The following were elected members of the Society :—JAMES PETER HILL, D.Sc.; J. YEATES, M.B., C.M., B.Hy.; E. S. SHAVE, F.R.C.V.S., M.R.C.S.; J. C. GRAVES, M.R.C.V.S.

Re the proposed contribution from the Society towards the expenses of the *International Catalogue*, it was proposed by Professor THANE, seconded by Professor ROBINSON, and resolved, "That the Committee of Management be requested to consider the financial position of the Society, and to report at the next meeting of the Society upon the position, with recommendations as to the course to be adopted."

The following communications were made to the Society :—

1. Dr H. M. JOHNSTON showed a series of painted plaster-of-Paris models of the wrist-joint.¹ These models, twenty in all, showed the relations of the carpal bones to one another in the various positions assumed by the hand. They were prepared from a series of dissections of the wrist, hardened by previously injecting the specimens with formalin.

2. Dr JOHN CAMERON gave a communication on a *Brain with Complete Absence of the Corpus callosum*.¹ The specimen is of particular interest in so far as it exhibits retention of the embryonic attachments of the "lamina terminalis."

3. Mr RALPH THOMPSON read a paper dealing with the important part the "calcar femorale" plays in connection with the variety of fracture of the neck of the femur known as extracapsular.¹

4. Professor FAWCETT read a paper on *the Ossification of the Sphenoid*.¹

¹ The paper will be published in full in the *Journal of Anatomy and Physiology*.

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Mr KEITH showed specimens illustrating the following points:—

(1) The muscular connections between the primary divisions (sinus, auricles, ventricles) of the human heart (see *Journal of Anatomy and Physiology*, April 1907).

(2) Peculiar neuro-muscular node at the junction of superior vena cava and right auricle.

(3) The arterial circle at the sino-auricular junction of the human heart. The circle receives tributaries from (1) a branch from right coronary that passes backwards between right auricle and aorta; (2) from a branch of the right coronary which passes upwards on the right lateral aspect of the right auricle; (3) a branch from the left coronary which reaches the superior vena cava by passing along the upper margin of the left auricle. The circle is formed in a similar manner in all mammalian hearts which have been examined.

(4) Congenital dislocation of the hip.

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